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PREFACE.

On March 14, 1914, the Rivers and Lakes Commission was called into a conference with Governor Edward F. Dunne, the Fish and Game Conservation Commission, representatives of the State Water Survey, Biological Department of the State University, and the Agricultural Department of the State University, to discuss the importance of problems growing out of the varied and conflicting interests in and to the Illinois River and its valley. The matters under consideration at this conference were the preservation of the public waters of the State, the reclamation of submerged lands, the preservation of fish, and future flood control.

As a result of this conference the Rivers and Lakes Commission employed Messrs. Alvord and Burdick, civil engineers, to make a survey and study of the Illinois River and Valley, compile the facts and report to this commission. This report has been put in printed form for circulation. We believe it contains such necessary information as will enable the Executive and Legislative departments of the State to adopt a policy that will prevent conflict between public interests and private interests and at the same time protect both.

The Illinois River furnishes from 10,000,000 to 24,000,000 pounds of fish per annum, or 10 per cent of the entire fresh water fish caught in the United States. After the opening of the Chicago Drainage Canal in 1900, due to the increased area of overflowed lands, the fish crop increased annually until the year 1908. Since then the yield has been falling off. This has been due to the reclamation of large areas of lakes and overflowed land by drainage and levee districts. The effect of this reclamation work is to confine the flood cross sections of the river and materially raise the flood heights. Messrs. Alvord and Burdick have presented in the report comprehensive and accurate investigations which show the effect of reclamation upon future flood heights and the value of conserving the lakes in the river valley for fish breeding and flood storage reservoirs.

Attempts are made by private parties to appropriate meandered or navigable lakes in the Illinois Valley which are the public property of the State. Acting on the policy outlined by the Legislative Committee on Submerged and Shore Lands, which led to the creation of the Rivers and Lakes Commission, this commission is now actively engaged in preventing such illegal seizure of the lakes in the Illinois Valley and conserving them for the use of flood storage, fish production, and the recreation of the public.

RIVERS AND LAKES COMMISSION,
ARTHUR W. CHARLES, *Chairman.*
LEROY K. SHERMAN, *Commissioner.*
THOMAS J. HEALY, *Commissioner.*

CHARLES CHRISTMANN, *Secretary.*
905 State Building, Chicago, Illinois.

PART I.

FINDINGS AND RECOMMENDATIONS.

The Honorable Rivers and Lakes Commission, State of Illinois.

GENTLEMEN: At your request we have made a careful study of the somewhat complex problems of the Illinois River relating to the control of floods with particular reference to the effect of the extensive reclamation of farm land within the past ten years and the rise and recent rapid decline of the very important inland fishery upon this stream. This report concerns principally that part of the river below LaSalle; above this place the river is of a different character and the problems considered do not exist.

We take pleasure in reporting to you the result of our study and findings as follows:

THE OBJECT OF THE REPORT.

It is the object of this report to answer the following general questions:

1. What future flood rates may reasonably be expected on the Illinois River?

2. Is the present waterway sufficient to accommodate the future floods?

3. What interests are affected by the past and probable future improvements in the valley? How is each interest affected and what is the relative importance of each?

4. What plan can be followed to correct the deficient waterway and to produce a maximum benefit to the local interests and to the public?

SUMMARIZED CONCLUSIONS AND FINDINGS.

Hereinafter will be found much of the data upon which the answers to these questions must be based. Before, however, proceeding to discuss these matters at length, we would briefly acquaint you with our principal findings and recommendations as follows:

1. PAST FLOODS. We conclude that the flood of 1904, which at most places upon the river is the greatest flood of recent years reached the rate of about 80,000 cubic feet per second at Peoria and 125,000 cubic feet per second at the mouth of the river. These rates are equivalent respectively to 5.94 and 4.48 cubic feet per second per square mile of drainage area.

At nearly all places upon the river the flood of 1844 reached a greater height than any flood of record before or since. This flood occurred during the maximum flood upon the Mississippi and the water passed

through a river valley entirely unimproved, very likely a veritable jungle. Under all these circumstances, it is questionable if the flow rates in the 1844 flood very much exceeded those in 1904.

2. FUTURE FLOODS. The stream records of the Illinois River, although a few records cover 40 to 50 years, are not sufficiently extensive to permit the formation of conclusions as to probable future maximum flood rates. So far as they are available they would appear to indicate that in the course of centuries the flood of 1904 might reasonably be expected about once in 50 years.

We have made a careful study of the great floods upon other rivers. It appears that such great floods are due to peculiar combinations of circumstances, such as, although infrequent, are likely to happen at any time, any place in central North America. The great floods upon the average are infrequent, but two great floods may occur in successive years.

It is our conclusion that the average flood expectancy, about once in 50 years, is a flood about 35 per cent greater in rate than the flood of 1904.

We further conclude that it is wise to protect the valley lands against the flood occurring upon the average of once in 50 years, namely, a flood about 35 per cent greater in rate than the flood of 1904.

3. PRESENT WATERWAY. In a state of nature the river in flood occupied its entire valley from hills to hills. For many miles in the lower river this flood plain averaged 3 miles in width and in the great floods from 7 to 9 feet in depth.

In the lower one-third of the river, farm land levees have reduced the width of the flood plain by about 80 per cent and have reduced the cross section of the flowing stream in a great flood to about 25 per cent of the available cross section of the 1904 flood.

Although a large part of the flood flow has always passed by way of the channel, the velocity being comparatively slow upon the land, it is our conclusion that the farm land levees are a menace to themselves, in that they have so restricted the flood water channel and are lacking in height, generally speaking, to such an extent that they are likely to be overtopped in a great flood. As the protection afforded to different districts is quite variable, it is evident that the lowest levees will suffer first and will tend to protect the higher levees. If all the districts are to be protected, however, a greater available flood cross section must be provided which may be accomplished in several ways, or the flood rates must be reduced through storage.

4. INTERESTS AFFECTED. Although many interests are affected to a minor degree, we find that the predominant interests in the river valley are agriculture and fishing. There are other important interests at Peoria and at a few of the other cities bordering the stream. These cities, however, without important exceptions are well above the ordinary floods and the municipalities in general are not greatly concerned with flood abatement.

5. FLOODED LANDS. We estimate the total water acreage below LaSalle in the flood of 1844 at 397,980 acres. Of this acreage 320,150 acres was flooded land. The first total includes 28,490 acres of river surface and 49,340 acres of lakes adjoining the river, the river and lakes surface being measured at the low water plane in 1901.

6. Levee districts. Since 1904 the construction of levees for the protection of the bottom lands has proceeded at a rapid rate. At the present time nearly all the bottom land below Beardstown has been reclaimed. The total leveed lands are estimated at 171,725 acres. These lands have been protected from floods at an estimated cost of $5,350,000 or about $30.00 per acre. The estimated full value of these lands is about $19,000,000, an average of about $112 per acre. Much of this land is valued at from $125 to $150 per acre.

Projected levee districts, so far as we can learn, aggregate about 49,250 acres.

It is estimated that the leveed lands produce crops to the value of $3,000,000 per annum and that when these districts are fully cultivated they will be capable of producing $5,000,000 per annum. These figures are based upon the crops of recent years at the prices that generally prevailed prior to 1913. At recent prices, the yield would be much greater.

It is estimated that with the projected districts completed and fully cultivated together with a small acreage upon the higher ground, now successfully cropped without levees, the total yield from agriculture will be approximately $6,500,000 per year.

7. Fisheries. Statistics indicate that the fishery of the Illinois River is more valuable than any other fresh water river fishery in the United States. It is exceeded only by the Great Lakes and the salmon industry of the Pacific Coast. The value of the catch to the fishermen amounts to 62 per cent of the fish product of the State and 10 per cent of the production of the United States.

The principal statistics of the fishery for the year 1908, according to U. S. Census, were as follows:

Total value of catch	$860,000
Value excluding mussel products	$721,000
Persons employed exclusive of shoremen	2,497
Capital employed	$557,000

8. Game fish and game. The statistics of fisheries do not include the fish taken for private use, either by the professional fishermen or sportsmen. The Illinois River and its adjacent lakes have long been known as the rendezvous for the sportsman in the taking of game fish and the shooting of water fowl. Competent local observers estimate that the money spent in the local river communities by sportsmen is fully equal to that derived from the commercial fishery. While the benefit to the State could hardly be measured by this expenditure, it indicates a certain value, greater or less in amount, that must be attributed to the preservation of the aquatic life of the stream. This use of the stream will doubtless increase as the value becomes better known through the improved water transportation facilities now shortly to be secured.

9. Fish prices. The statistics above quoted are based upon the average price of about 3 cents per pound to the fishermen. About two-thirds of the catch at present is German carp, which sells for 2 to 2½ cents per pound. Other varieties sell from 5 to 10 cents per pound.

Carp and other fish return from 12 to 15 cents per pound to the fishermen of Europe or four or five times the American price. The time

will doubtless come when American prices will be more nearly equal to those of Europe. At foreign prices the 1908 catch of the Illinois River would have amounted to from $3,000,000 to $3,500,000.

10. RISE AND DECLINE OF FISHERY. We find that the annual catch upon the Illinois River has gradually increased from about 6,000,000 pounds in 1894 to 12,000,000 pounds in 1900 and 24,000,000 in 1908.

No complete statistics are available since 1908, but it is well known that the catch has very rapidly decreased within the past five years. The statistics at Havana would seem to indicate that the yield at present is only about one-third of the banner yield of 1908.

The great increase is probably largely accounted for by the rapid increase of the German carp, which first began to appear in the catch of the Illinois River at about the date of the earliest statistics above mentioned. All fish life was undoubtedly stimulated by the increased stages of water that have prevailed since 1900.

The decline since 1908 is probably due to a number of causes including the lesser flood stages prevailing in recent years and the large number of lakes excluded from the river through the construction of agricultural levees shutting off the breeding and feeding grounds of fish and the places where the larger part of the seining has been done. About 17,740 acres in lakes have been enclosed by levees amounting to about 36 per cent of the original lake acreage. Most of these lakes have been enclosed since 1908.

11. INCREASED FISH YIELDS. We have examined such authentic statistics of foreign fisheries as could be found, particularly the statistics of the German fisheries.

It is our conclusion that at the present prices of fish and labor, a commercial fishery, that is, one in which the fish are bred, fed and sold as a distinct business, could not be profitable.

It would seem, however, that there is prospect of a good profit by intelligent fish culture in the ponds and water courses remaining within the levee districts, providing that the industry is carried on as an adjunct to farming in much the same way that poultry is ordinarily raised upon the farm. This would utilize a water acreage that otherwise could produce no revenue and could serve no useful purpose except to store the flood waters in the course of passage to the drainage ditches.

12. PERMANENCY OF THE FISHERY. If the fishery is to remain commercially important, means must be provided to take the place of the breeding grounds formerly furnished by the shallow waters of the lakes and sloughs which have been reclaimed.

13. PREDOMINANT INTEREST. In the light of the figures before us we must conclude that agriculture is the predominant interest of the valley, that it now furnishes and will hereafter furnish a much greater addition to the wealth of the State than is produced or can probably be hereafter produced by the fisheries. In so far as possible, however, both interests should be promoted in harmony.

14. RESERVOIRS AND FISH CULTURE. In Europe, where the flood problems and the fisheries have been studied for a longer time than in America, the suggestion has been made to promote the fisheries and reduce the floods upon the diked rivers by admitting water to certain of the leveed districts in rotation during each spring season and allowing

the water to return to the stream during the low water season. All this with the object of reducing the spring freshets, artificially providing overflowed land for the breeding and rearing of young fish and the periodical enrichment of the land by the sediments of the flood waters.

We have endeavored to demonstrate the practicability of such a scheme upon the Illinois River. The practicability of this scheme is hereinafter discussed in connection with the remedy for floods.

15. FUTURE FLOODS AND PRESENT LEVEES. No great flood has occurred upon the river since the occupation of the valley by levees approaching the present scale of development.

The nearest approach to a great flood was the freshet of 1913. Although this flood is estimated to have been slightly less in volume than the flood of 1904, its elevation in the vicinity of the La Grange Dam, near the head of the most extensive levee system, was 3 feet greater than the flood of 1904 and substantially the same as the exeremely high water of 1844. The levee districts completed since 1913, including those now in process of construction, will still further restrict the flood water passage.

16. GREAT FLOODS IN LEVEED VALLEY. It is estimated that if the 1904 flood should be repeated under the same conditions of water level in the Mississippi, a number of levee districts would be overtopped.

If this flood should be repeated under the high water conditions in the Mississippi that prevailed during the flood of 1844, a large number of the agricultural levee districts would be flooded.

It has been previously concluded that a flood 35 per cent greater in rate than the flood of 1904 may reasonably be expected to occur. If such a flood should enter the Mississippi at the height of water prevailing in 1844, more than half of the levee districts would be flooded, and under the conditions of levee construction likely to prevail in the future nearly all the levee districts would be flooded, and the water would reach a height about 5 feet above the high water mark in 1844 in the vicinity of the La Grange Dam, with lesser differences up-stream and downstream.

In reference to the flooding of levee districts it should be noted that the lowest levees will be flooded first and to a certain extent will serve as safety valves to protect the districts having higher levees. The flooding of a large number of districts near the apex of the flood will probably arrest the further rise of the water unless the flood is greatly prolonged. Therefore, to increase the elevation of the lower levees serves to decrease the safety of the high levees until all have been increased to such height that a great flood may pass away between the levees.

17. LEVEES AND FLOOD RATES. There is no question but that the exclusion of the flood waters from the bottom lands through the construction of levees has a tendency to increase the flood run-off rates of a stream. We have investigated this matter quite carefully as applied to the Illinois River particularly in the measured flood of 1904, assuming it to pass through the present levee system. It is estimated, however, that the net effect of all the levee districts so far constructed would probably increase the maximum flow rate only about 5 per cent and when the bottoms are fully leveed about 10 per cent. This rather unexpected result is accounted for by the fact that in an excessive flood, such as the

flood of 1904, the valley is practically filled with water several days before the apex of the flood and the maximum flood rate occurs at a time when the gage height is nearly stationary for several days both before and after the apex. A smaller stream or a more flashy stream would doubtless make a better utilization of the storage in its valley.

18. APEX STORAGE. A much greater effect can be produced in mitigating the floods if certain large reservoirs could be held empty and the flood waters only admitted when the flood is approaching maximum rates and the water passing into the reservoirs could be regulated so that all surplus water above a pre-determined rate could be accommodated.

We have investigated this proposition and find that in the lower river at Kampsville for instance, the flood heights are most largely governed by the Mississippi River. In this vicinity storage on the Illinois River could accomplish nothing material. The present levee districts are not adapted to flooding, but if we should assume that all future levee districts, which would be substantially equal in storage volume to the districts at present constructed, should be so built and so operated that they could be flooded without great damage except the loss of crop when flooded, then we estimate that there would be about 850,000 acre-feet of storage above the La Grange Dam, which if used to the best advantage, would reduce the flood flow rate about 25 per cent at Beardstown, making a difference in the height of the water of about 3.4 feet.

A similar estimate at Peoria indicates that through storage it would be theoretically possible to reduce a great flood about 2½ feet.

It is our conclusion that storage as above outlined would be effective in reducing the flood heights in amounts varying from practically zero at the Kampsville Dam to about 3½ feet at Beardstown and 2½ feet at Peoria.

19. INCREASED FLOODWAY. In general there are three ways to increase the available prism for the passage of flood waters.

The width of the flood stream may be increased by setting the levees back a greater distance from the river bank. We find that this remedy is impracticable on account of cost except where new levees are to be built. We recommend, where levees are built upon both sides of the river at any place above the junction of the Sangamon, that the distance from center to center of levees, measured across the river, be not less than 1,200 feet and where reasonably possible 2,000 feet. Below the Sangamon the land is nearly all leveed.

The flood water prism might also be increased by lowering the bed of the river, as might be accomplished in the construction of a deep waterway. In our opinion, dredging operations undertaken especially for this purpose would be too costly as compared to other remedies. So far as we can determine, none of the projects for improved navigation would affect the flood water levels any sufficient amount to be of material benefit.

20. HIGHER LEVEES. It is our opinion that the available cross section for flood waters can be most economically enlarged by increasing the height of the levees. It seems to us that the circumstances warrant the building of levees to a height about 3 feet above a great flood, assuming it to enter the Mississippi River at about the height of the flood of 1844. The excess height of levees is recommended to provide for wave

wash and in emergency as a small factory of safety to prevent disaster in case of a greater flood. It is believed that in the protection of these farm lands, the danger from loss of life is small and, therefore, that it is not wise to provide against a flood of extremely rare occurrence or to provide a factor of safety that would be justified in the protection of a city where great loss of life might result from the unexpected.

To comply with the above recommendation, the higher levees at present would be increased from 2 to 3 feet. The lowest of the levees lie about 6 feet below what we regard as a desirable elevation. As nearly as we can estimate from rather incomplete data, the cost of bringing all the present levees up to the desirable plane would be about $2,532,000. The total expenditure, including this item and also the total cost of all future levee districts, is estimated at about $8,154,300.

21. Levee heights with storage. If all future levee districts should be so built that they might be utilized for storage of the apex flood waters, the necessary levee heights in the upper three-quarters of the river could be reduced from 2 to 3 feet, but this would still require that nearly all the levees should be increased in height at a total estimated cost of about $1,592,000. The total expenditure, including this item and also the total cost of all future levee districts, is estimated at $5,389,000.

22. Revenues compared. We have carefully considered the relative merits of the above suggested means for relieving the flood situation and the promoting of fisheries, particularly as to the practicability of using storage reservoirs for these purposes.

Giving the storage proposition the benefit of all the doubts including the practicability of manipulating the reservoirs during the flood and the benefit accrued to the fisheries, we estimated that the largest financial return to the community will be effected through the utilization of the bottom-lands for agriculture and increasing the height of levees such an amount as is necessary to protect the lands.

23. Means of accomplishment. It would seem proper that the additional levee protection should be affected by private enterprise.

It is believed to be the duty of the State, however, to advise the land owners as to conditions and through the Rivers and Lakes Commission to regulate future constructions or alterations in present levees, so far as the powers of the commission extend. Advice to the land owners is the proper function of the State, for no individual land owner is in a position to determine these facts for himself.

It is not probable that all the districts can profitably increase their levees to the recommended height, for some of the small districts, particularly those not equipped with farm improvements and public improvements, would be injured in case of flood only to the extent of a lost crop and repairs to the levee system. Such districts might better suffer the loss from the occasional flood than to protect against the indefinite future. The proper course in this matter will be determined by the value of the crops and improvements and the frequency of the floods. The decision of a particular district will not affect the community outside the district except where there might be danger to life.

24. PROMOTION OF FISHERIES. The predominance of the agricultural interest does not require that the fisheries of the Illinois River should be abandoned.

It is believed, notwithstanding the levee districts present and future, that a scientific utilization of the remaining public waters, including the river and twenty or more meandered lakes together with the best use of the remaining undiked bottoms and the spaces between the river banks and levee toes, will result in the maintenance of a valuable fishery.

We recommend that the State Laboratory of Natural History be empowered to investigate and determine the best means for promoting the fishery interests in the public waters and the adjacent undiked lands. We should hope that a practicable program might be worked out that would permit of great help to the fisheries and at the same time provide game and fish preserves, usable by the public under proper restriction.

We understand that the damage claims, filed against the Sanitary District up to December 31, 1912, for flowage damage to land below Utica, amounts to $4,539,980, and that additional claims not yet filed will raise this total to about eight million dollars. The last named figure is equivalent to about fifty-four dollars per acre of land outside of the levees, and below the flood plane of 1844.

Although these claims are no doubt excessive, it would seem, as has been suggested, that if a working arrangement could be devised, the State might profitably combine with the Sanitary District in the purchase of some of these lands.

In view of the large expenditures made by our cities for park purposes and the expenditures of the national government in the preservation of the national parks, it would seem that there is a field for profitable investments by the State, which wisely administered would accrue to the great benefit of the commercial fishery and to the people of the State.

We have endeavored above to briefly outline our principal conclusions and findings. In the body of the report which follows will be found a full discussion of these matters and much of the original data upon which the discussion and conclusions are based.

PART II.

DESCRIPTION OF ILLINOIS RIVER—ITS WATERSHED AND HYDRO-GEOLOGY.

In many respects the Illinois River is one of the most remarkable streams in the United States. Its past importance as an avenue of water commerce, the possibilities of its future in this respect, its fresh water fisheries, its use as the main sewer, so to speak, of the second city in the country, and more recently, the agricultural development on its bottom lands through the construction of levees, all have led to perhaps more thorough studies, with various objects in view than has been received by any other of our rivers.

The Illinois River is formed by the junction of the Des Plaines and Kankakee Rivers, 273 miles by river from its mouth at Grafton. It flows nearly west 62 miles to the Great Bend near Hennepin, and thence pursues its course nearly south, 211 miles, to its junction with the Mississippi. Its watershed, estimated at 27,914 square miles, lies principally within the State. The upper waters of the Des Plaines and Fox Rivers drain 1,080 square miles in Wisconsin, and the headwaters of the Kankakee furnish the outlet for 3,207 square miles in Indiana.

The principal tributaries are the Kankakee, 5,146 square miles, the Des Plaines, 1,392 square miles, the Fox, 2,700 square miles, and the Vermillion, 1,317 square miles, all joining the upper river above Hennepin. Below the Great Bend the Illinois receives the Mackinaw, 1,217 square miles, Spoon River, 1,817 square miles, the Sangamon, 5,670 square miles, and Crooked Creek, 1,385 square miles. The remaining watersheds are small, none exceeding 1,000 square miles. About two-thirds of the tributary watershed lies to the southeast. In the lower 60 miles no important drainage reaches the stream from the west, the dividing line between the Illinois and the Mississippi which here flow in parallel courses, lies not more than ten miles westward.

The greater part of the drainage area is a typical Mississippi valley prairie region. The slopes are flat to the north and east, but become more rolling in the lower half of the watershed. The soil is a rich black loam 1 to 4 feet in thickness, very largely underlaid with boulder clay.

The upper waters of the Fox River serve a poorly drained lake region, largely in Wisconsin, and more than half of the Kankakee watershed comprises the marsh region of northern Indiana, at this time partially but not completely drained and reclaimed. The dividing ridge of the basin ranges in elevation from 700 to 1,000 feet above the sea, and the river itself ranges from 499 feet at its head to 412 feet at its mouth.

THE RIVER BOTTOMS.

From the head of the river, to La Salle, a distance of 50 miles, the fall of the stream is comparatively rapid, dropping about 53 feet. The

stream is flanked on either side by bluffs or sharply rising ground nowhere more than two miles apart, and narrowing to about one-quarter of a mile near Seneca. The bottom lands are comparatively high, and in general rise toward the base of the bluffs. High water is of comparatively short duration, and it does not prove advisable to dike the farm land.

Below La Salle the conditions are quite different. In 223 miles, the fall is only 33 feet, and for the first 80 miles only 6 feet. As in the upper river, the bottoms are flanked by bluffs or hills, but the flood plain is wider, ranging from 1½ to 3 miles above Peoria, 3 to 5 miles near Havana, and 6 to 7 miles near Beardstown, at the mouth of the Sangamon River. In the lower 60 miles, the bottom lands are generally 3 to 4 miles in width. From La Salle to the Mississippi, the bottom land subject to flood aggregates about 400,000 acres or 620 square miles. The immediate banks of the stream are nearly everywhere higher than the bottoms further inland, gradually falling away to lakes, ponds, and marshes near the foot of the bluffs. Some exceptions to this rule are found at the deltas of the larger tributaries.

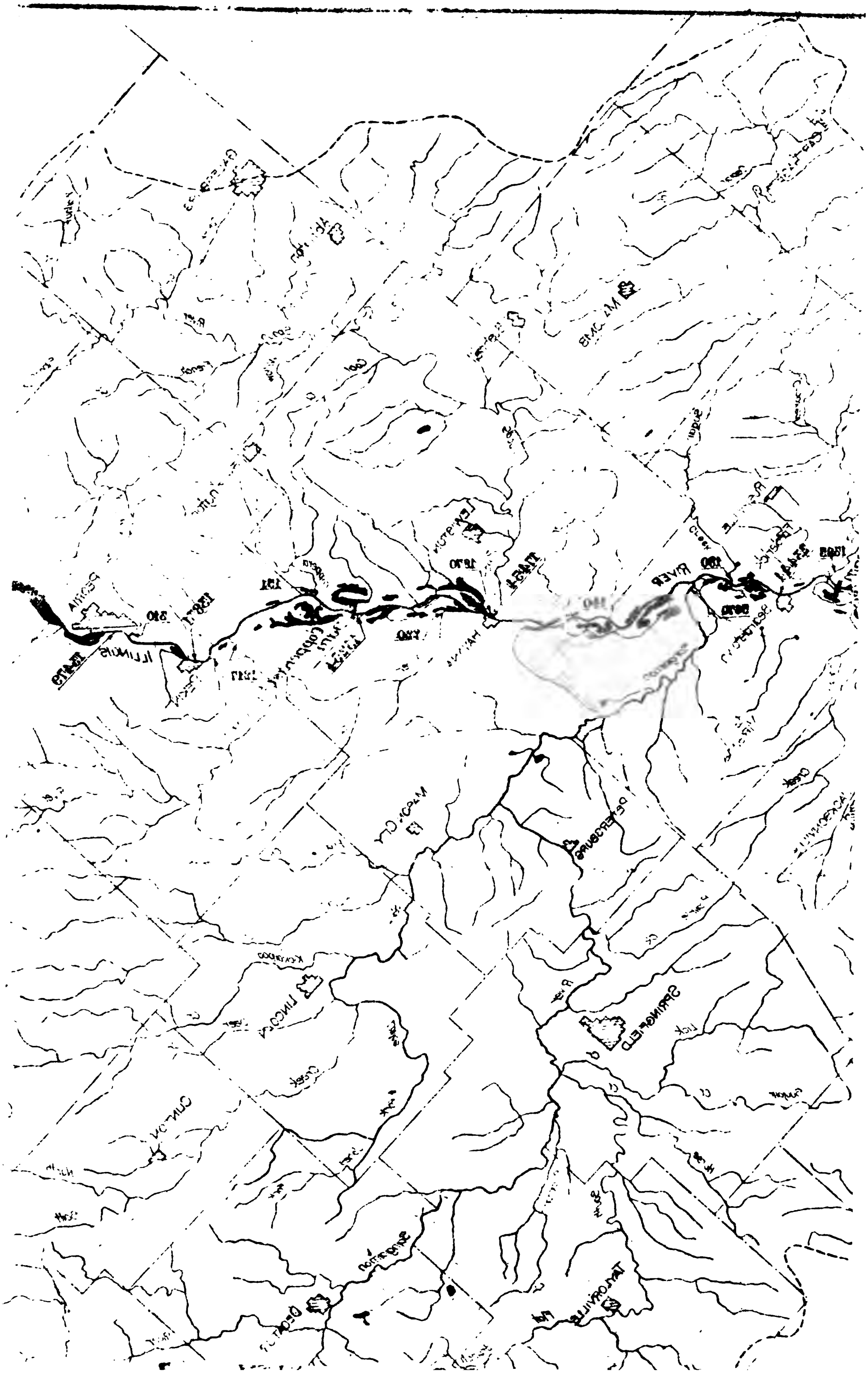
In the upper river as far south as Beardstown, the river banks lie generally from 7 to 12 feet above low water, averaging about 10 feet. The lakes, many of them quite large, are connected with the river at low or medium stages of water and lie at approximately the same elevation as the river, rising and falling with it. The low water connection is always at the foot of the lake. At moderate stages of flood they are connected with the river at their upper ends also, the lakes receiving and carrying a portion of the flood flow in its passage down the valley, and also acting as storage reservoirs, tending to reduce the maximum flow rate of the flood. In the lower river below Beardstown, the immediate banks of the stream are higher, the filling of the bottom lands has progressed further, and the lakes are smaller, many of them lying 10 feet or more above low water in the main stream. They are thus only invaded by river stages considerably above normal.

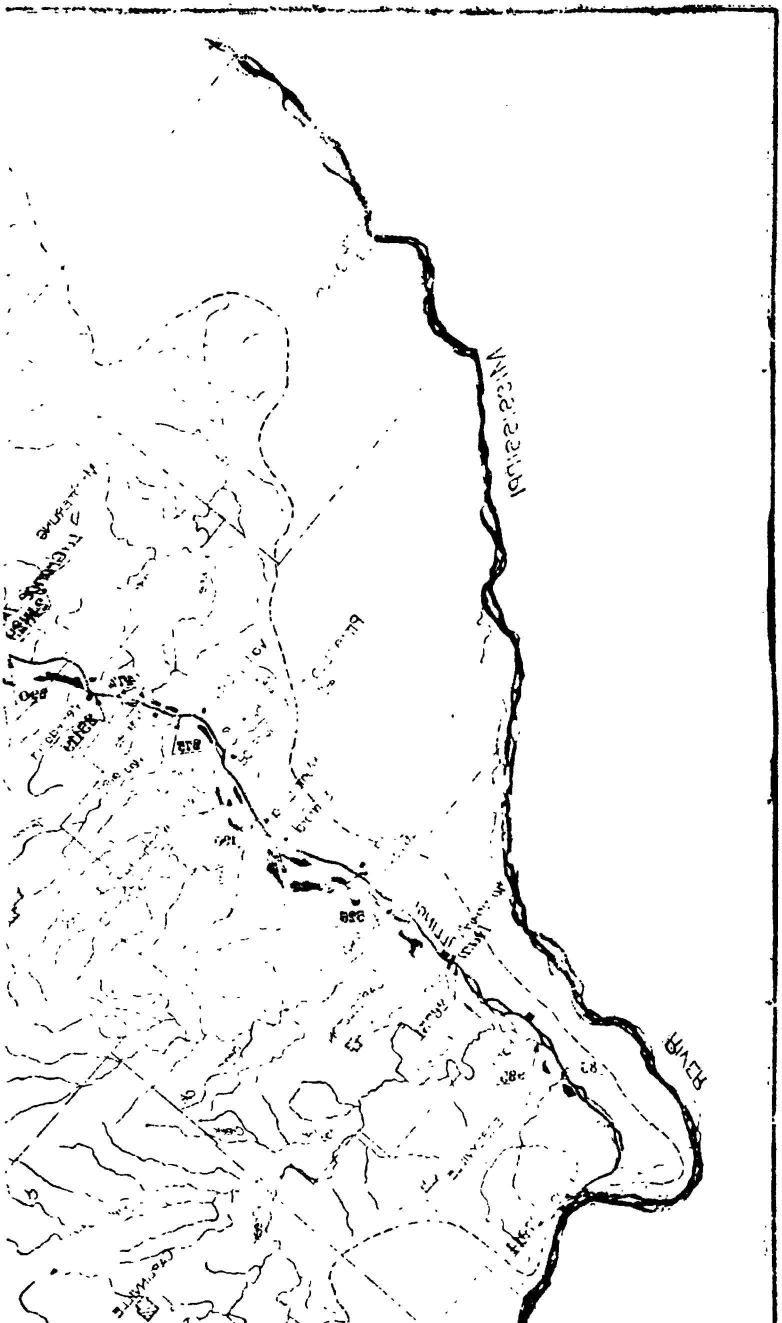
The course of the river is unusually direct, the filling of the flood plain having been insufficient to induce the tortuous courses of the Mississippi and like streams. Throughout the greater part of its length, particularly in the lower 60 miles, the stream follows the base of the western hills, with occasional diversions toward the center of the valley where the stream has been pushed outward by the deposit at the mouth of an important tributary.

Throughout its course the low water banks of the stream are thickly overgrown with trees and brush, and in the lower reaches of the river particularly, the bottoms are veritable jungles of trees, shrubs and climbing vines. In its natural state all ground within a few feet of the low water line in river and lakes was thus thickly overgrown, the only open places being the lakes and ponds and their low lying borders submerged for a large part of the year, and during the low water season covered with swamp grass and rushes.

GEOLOGY.

The geological history of the Illinois River is instructive. It serves to show the reasons governing the peculiarities of the river bottom topo-





graphy, indicates tendencies still operative but somewhat modified, and materially assists in final conclusions as to what future floods may be expected, through comparison with other streams upon which longer flow records are available. It serves to indicate why some excessive flood rates are not applicable to the Illinois.

The territory drained by the Illinois is almost entirely within the area of glaciation. From the headwaters to Peoria, the glacial débris belongs to the Wisconsin period. From Peoria to the southern line of Pike County, the drift is Illinoisan capped by *loess,* a fine-grained clay-like formation. From this place southward the drainage area is quite small, especially to the west of the river where the area is unglaciated, but the surface is largely covered by loess. To the east there is a moderate amount of drift also capped by loess. This visit of the glaciers has had a very marked effect upon the character of the present streams draining the region of their occupation, and the watershed of the Illinois River is principally characteristic of the glacial epoch. The depth of the glacial debris overlying rock except in exceptional instances, varies from 20 feet to several hundred feet, the latter depth of covering predominating.

It is well known that when materials are eroded by flowing water, the heavier particles are dropped first and the lighter materials are carried longer distances. Thus, in the valley of the Mississippi River, the upper portion of its ancient channel is paved with coarse sand and gravel. Further southward in Illinois, Iowa and Missouri, the deposits are finer, coarse gravel being scarce. Sand where found is usually coarse to the northward, and becomes finer to the southward. In the lower river, the later deposits are of finely divided clay, and at New Orleans for nearly all the year, the water is charged with clay particles so fine that many weeks of settling are required to deposit them. The water has rid itself of sands and gravels except in the greatest floods.

Similar facts are observable in the territory occupied by the glaciers. The rocks over which they moved were worn, scraped and broken, resulting in debris varying from the largest boulders to finely divided dust. The melting waters took up these materials, transported them under and through the ice, and upon emerging, first deposited the boulders, then the gravel, then the coarse sand, then the fine sand, and lastly the more finely divided clay. Likewise where the glaciers rested for long periods, in their recession the melting waters deposited all kinds of debris which were washed over by the melting of the ice further north, and the materials were sorted in the order above described, the coarser materials in the north and the finer materials in the south.

This sorting of the glacial debris is the principal cause of marked differences in the flow characteristics of the streams in the northern United States. In the north in Wisconsin and Michigan, and parts of New York and New England, the sands and gravels predominate. A large part of the rainfall is absorbed by the soil where it is stored and given up again to the streams with relative uniformity throughout the year. Streams are thus produced that yield annually 50 per cent of the rainfall, or 15 to 20 inches per year, and further, by reason of the ground storage, the flow is constant and of relatively large volume in the driest seasons.

Further south in Illinois, Iowa and in northern Indiana, the sand and gravel is largely confined to narrow belts in the valleys of the water courses, and nearly all the streams drain regions where clay largely predominates, and although clay will absorb a large amount of water, it does so only slowly and gives it up with such reluctance that even the larger streams cease to flow in the dry seasons. The surface, although for the most part well drained, is relatively flat. The water remains for a long time upon the surface; the absorption is high and as it cannot be drained to the streams, is largely absorbed by luxuriant vegetation. The flood rate is mitigated by the storage in the wide, flat bottom lands, over which although the water is in transit and ultimately drains away, it moves but slowly. All this results in streams that naturally deliver not more than 25 or 30 per cent of the rainfall, or 7 to 15 inches per year.

The Illinois and its tributaries are of this character. The flat prairie lands are thoroughly saturated in the spring and give up the water stored only to the roots of vegetation. The immediate run-off in great storms is high, but is slow in its passage through the principal arteries of drainage. Thus, we have streams of small annual run-offs, extremely small summer flows, and flood flows intermediate between those of the sand and gravel watersheds of Wisconsin and Michigan, and the unglaciated or slightly glaciated regions of Kentucky, southern Indiana, Ohio, Pennsylvania and generally in the southeastern states.

These characteristics of regional streams should be kept in mind in examining the data hereinafter presented upon the flood flows of the eastern United States as bearing upon the probabilities in the Illinois River. They serve to explain the improbability upon the one hand of the extremely high run-off rates of the Ohio and Pennsylvania streams, and upon the other hand, the extremely small flood run-offs from some of the watersheds in northern Michigan and Wisconsin. Upon the Illinois River proper, and indeed upon some of its tributaries, storage is a predominating influence and serves to reduce the flood flow rates very near to that of the rivers draining the coarse glacial drifts.

For an explanation of the topography of the present river valley, we are also indebted to the research of the geologists. The sharp distinctions between the physical features above and below the Great Bend near Hennepin are explained by the very different geological history of these two reaches of the stream. The lower Illinois from the Bend southward occupies its pre-glacial channel which formed a drainage outlet for a very much larger area than now drains through this portion of the river. There is circumstantial evidence that the Rock River, now a tributary of the Mississippi at one time entered the Illinois near the Great Bend, and was subsequently diverted by glacial action. This enlarged drainage area and the great volumes of water that poured from the glaciers serve to account for the wide and deep river valley that was excavated. In places, the prehistoric stream reached a width not less than 15 miles.

The present valley from the Great Bend east is of more recent origin and owes its existence to its temporary occupancy by the drainage from the glacial Lake Chicago. As stated by Leverett:

"This portion of the Illinois Valley, although of post-Wisconsin age, has a channel more than a mile in average width and nearly 100 feet in average depth. Yet at present it is the line of discharge for an area of only 12,000

square miles. The influence of the waters discharged from the Lake Chicago and also from the lobes north and east of the Kankakee is plainly shown in the great size of this valley."

In the escape of these waters it was necessary to cut through a glacial moraine near Marseilles, which for a considerable time, no doubt, impounded a large lake in that part of the river adjacent to Morris. Below the Marseilles moraine, the channel was cut to a depth of 50 to 75 feet, and is still cutting, the river running upon a rock bottom.

The great quantities of debris brought down by the glacial floods were deposited in the wide and deep valley of the lower Illinois; also no doubt the scour from the cutting in the upper Illinois. The recession of the glaciers and the resulting diminished floods, particularly the new outlet formed for the Great Lakes waters at Niagara, a comparatively recent geological event, so greatly diminished the water supply that the filling of the lower Illinois valley was not so far advanced as other streams of the Middle West, and it remains today only partially filled, with the thread of the stream running substantially straight in its pre-glacial channel, flanked by numerous lakes and lagoons which doubtless would have been largely obliterated but for the important changes in water supply heretofore mentioned.

The building up of the bottoms has continued in recent times and is going on today, but the rate of filling is much diminished by the decreased water supply, and consists of the finer silt only, which when the flood invades the bottom lands, is quickly dropped in the relatively still waters and thus accounts for the height of the banks immediately adjoining the stream and the general slope of the land away from the river bank toward the inland lakes. The filling of the lakes is now very slow as much of the water borne material is dropped immediately outside the thread of the channel.

In the upper river, although deposits of considerable magnitude took place in the Morris Basin, the more recent period has been one of cutting only. The deposits brought down by the tributaries were largely cut away in the drainage of the Morris Basin, and on account of the more rapid fall in this part of the river, the cutting continues to a relatively small extent. In the lower river the cutting is absent and the bottoms are building, although slowly by reason of the diminished water supply.

PART III.

FLOW AND GAGE HEIGHTS—DAMS—SUBMERGED LANDS.

As would be expected from the topography and geology of the drainage basin, the Illinois River is a stream of extremely small natural flow in drouth, and on account of its wide bottom lands and the great opportunity for flood water storage, the maximum flood discharge is relatively small, and the duration of flood conditions is relatively long.

PREVAILING GAGE HEIGHTS.

Gage records of water stage are recorded at numerous places throughout the length of the river, particularly the records of headwater and tailwater at the two U. S. dams at Kampsville and La Grange, the two State dams at Copperas Creek and Henry, the observations of the Weather Bureau at Beardstown and Peoria, and several other gages maintained by municipalities and the railroads which cross the stream. Table No. 1 shows the locations of all gages so far as known, with a statement of the length of time covered by each record. The data is very complete for the past twenty years. A number of the gage records are fairly complete back to 1880. The Peoria gage record is continuous, excepting a few years, back to 1869.

TABLE NO. 1—LIST OF GAGES ON ILLINOIS AND DESPLAINES RIVERS.

Compiled from report of United States Engineers on 14-foot waterway.

Number.	Miles above Grafton.	General location.	Elevation above Memphis datum.	Reads up or down.	Years covered by records.	By whom established.	Custodian of records.
1	0.0	Grafton Dock	219.60	Up	'79–'92	U. S. Eng'rs	
1	0.0	Grafton Dock	410.96	..do	'94–'14	..do	U. S. Weather Bureau, St. Louis—U. S. Engineers, Peoria.
2	7.0	Deer Plain	413.37	..do	'78–'80	..do	
3	21.0	Hardin	414.61	Both	'78–'80	..do	
4	31.5	Columbiana	416.47	Both	'78–'80	U. S. Eng'ers	
4	31.5	Kampsville	416.82	Up	'81–'93	..do	
4	31.5	Kampsville Lock—lower	409.10	..do	'94–'14	..do	United States Engineers, Peoria.
4	31.5	Kampsville Lock—upper	409.13	..do	'93–'14	..do	United States Engineers, Peoria.
5	43.1	Pearl—C. & A. Bridge	419.70	..do	'78–'14	..do	U. S. Eng'rs and C. & A. R. R. in 1904—U. S. E., C. & A. R. R. and Sanitary Dist., 1914
6	61.7	Valley City—Wabash Br	421.75	..do	'78–'80 '83–'14	..do	Wabash R. R., Decatur—U. S. Engineers, Peoria.

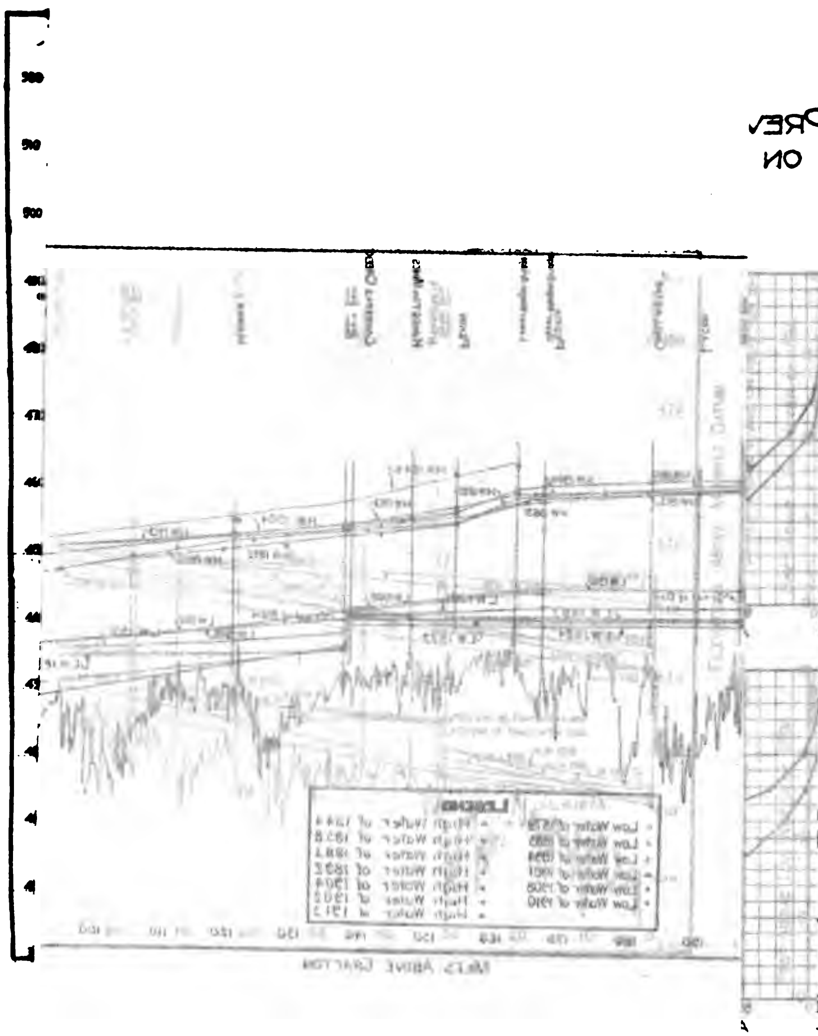
TABLE NO. 1—Continued.

Number.	Miles above Grafton.	General location.	Elevation above Memphis datum.	Reads up or down.	Years covered by records.	By whom established.	Custodian of records.
7	71.3	Meredosia—Wabash Br.	424.22	Up	'78–'81 '84–'14	U. S. Eng'ers	Wabash R. R., Decatur—U. S. Engineers, Peoria.
8	77.6	LaGrange Lock site	425.28	Both	'82–'89	..do	
8	77.6	LaGrange Lock—lower	418.23	Up	'90–'14	..do	United States Engineers, Peoria.
8	77.6	LaGrange Lock—upper	418.23	..do	'90–'14	..do	United States Engineers, Peoria.
9	88.9	Beardstown—C. B. & Q. Br.	427.25	..do	'78–'84 '85–'14	..do	U. S. W. B., 1904—U. S. W. B., U. S. Eng'rs and San. Dist. in 1914.
10	97.5	Browning	436.82	..do	1903	..do	San. Dist., Chicago.
11	103.0	Sharp's Landing	429.49	..do	'78–'80	..do	
12	108.5	Holme's Landing	439.37	..do	1903	..do	
13	111.5	Bath	430.22	..do	'78–'79	..do	San. Dist., Chicago.
14	120.0	Havana Highway Bridge	431.67	..do	'78–'81 '95–'04 '07–'14	..do	U. S. Eng'rs, in 1904—U. S. Eng'rs and San. Dist. in 1914.
15	128.0	Liverpool	438.60	..do	1903	..do	San. Dist., Chicago.
16	137.0	Copperas Creek	432.73	..do	'73–'76	Ill. Canal Com.	
16	137.0	Copperas Lock—lower	427.75	..do	'77–'14	..do	United States Engineers, Peoria.
17	137.0	Copperas Lock—upper	432.73	..do	'77–'14	..do	United States Engineers, Peoria.
18	146.5	Kingston Mines—landing	434.44	..do	'03–'04	U. S. Eng'rs	U. S. Eng'rs, Peoria 1904—San. Dist., Chicago, 1914.
19	153.5	Pekin Highway Bridge	438.57	..do	'92, '98–'04 '12–'14	City of Pekin	U. S. Eng'rs, in 1904—U. S. Eng'rs and San. Dist. in 1914.
20	162.0	Peoria & Pekin Union R. R. Br.	435.53	..do	'03–'04	U. S. Geo. Sur.	U. S. Geo. Survey.
21	163.0	Peoria Lower Free Bridge	435.82	..do	'67–'14	U. S. Eng'rs	U. S. W. B., St. L. and Peoria.
	163.0	Peoria Lower Free Bridge	588.36	Down		Sanitary Dist.	
	164.5	Peoria—U. S. Boatyard	435.82	Up	'10–'14	U. S. Eng'rs	United States Engineers, Peoria.
22	166.0	Peoria—upper bridge	413.10	..do	'94–'14	Peoria W. W.	Peoria Water Wks., Peoria.
	172.3	Mossville (½ mile above)	588.40	Down		Sanitary Dist.	
	180.0	Chillicothe, San. Dist.				..do	San. Dist., Chicago.
	181.3	Chillicothe (1½ mile above)	588.52	Down		..do	
23	182.0	Santa Fe R. R. Bridge	436.41	Up	'03–'04	U. S. Eng'rs	U. S. Eng'rs in 1904—San. Dist. in 1914.
	187.3	Sparland (1¾ miles below)	588.13	Down		Sanitary Dist.	
24	189.0	Lacon Highway Bridge	442.04	Up	'03–'04	U. S. Eng'rs	United States Engineers, Peoria.
	189.0	Lacon Highway Bridge	588.18	Down		Sanitary Dist.	
	191.0	Lacon (2 miles above)	588.20	..do		..do	
	194.5	Henry (2 miles below)	588.13	..do		..do	
	195.5	Henry Br. (¼ mile below)	587.89	Down		Sanitary Dist.	
	196.0	Henry (city)	587.89	..do		..do	San. Dist., Chicago.
25	196.5	Henry Lock—lower	436.64	Both	'69–'14	Ill. Canal Com.	Illinois Canal Com., Lockport—U. S. Eng'rs, Peoria.
26	196.5	Henry Lock—upper	443.79	Up	'71–'14	..do	Illinois Canal Com., Lockport—U. S. Eng'rs, Peoria.
	198.5	Henry (2½ miles above)	587.82	Down		Sanitary Dist.	
	201.0	In Lake Senachwine	587.73	..do		..do	
	202.0	In Lake Senachwine	587.87	..do		..do	
	207.5	Hennepin	587.56	..do		..do	San. Dist., Chicago.
27	210.5	Bureau—Lock No. 1	446.43	Up	'03–'04	U. S. Eng'rs	United States Engineers, Peoria.
	210.5	Bureau Junction	587.60	Down		Sanitary Dist.	
	212.0	Depue (1½ miles below)	587.56	..do		..do	

TABLE NO. 1—Continued.

Number.	Miles above Grafton.	General location.	Elevation above Memphis datum.	Reads up or down.	Years covered by record.	By whom established.	Custodian of records.
	214.0	Marquette (1 mile below)	587.48	Down		Sanitary Dist.	
	218.3	Spring Valley	587.39	do		do	
	218.3	Spring Valley	587.31	do		do	
	220.8	Peru (1¼ miles below)	587.30	do		do	
28	222.5	Peru Wagon Bridge	442.98	Up	1889	U. S. Eng'rs	
28	222.5	Peru Wagon Bridge	443.45	Up		do	
29	222.5	Peru Wagon Bridge	587.02	Down		Sanitary Dist.	San. Dist., Chicago.
30	223.0	La Salle Lock 15	435.36	Up	'67–'77 '93–'14	U. S. Eng'rs	Ill. Canal Com. in 1904—U. S. W. B., San. Dist. and U. S. Eng'rs, 1914.
30	224.0	La Salle Highway Bridge	587.08	Down		Sanitary Dist.	San. Dist., Chicago.
30	224.0	La Salle acqueduct	587.14	do		do	
30	226.0	La Salle (2 miles above)	587.12	do		do	
31	230.0	Utica Highway Bridge	444.06	Up	1900	U. S. Eng'rs	
31	230.0	Utica Highway Bridge	587.14	Down		Sanitary Dist.	
32	234.7	Ottawa (below Buf. Rock)	587.14	do		do	San. Dist., Chicago.
32	235.0	Buffalo Rock	451.00	Up	1883	U. S. Eng'rs	
	236.0	Ottawa (3½ miles below)	587.02	Down		Sanitary Dist.	
	237.5	Ottawa (2 miles below)	587.06	do		do	
	239.5	Ottawa—C., B. & Q. Bridge	587.12	do		do	
33	236.2	La Salle County Poor Farm	453.90	Both	1900	U. S. Eng'rs	San. Dist., Chicago.
34	239.5	Ottawa—C. B. & Q. Bridge	587.05	Down	'03–'04	Sanitary Dist.	
	239.5	Ottawa—C. B. & Q. Bridge	594.35	do		do	
35	239.6	Ottawa—between bridges	453.92	Both	1883	U. S. Eng'rs	
36	239.8	Ottawa Wagon Bridge	454.74	do	1900	do	
37	240.0	Ottawa—above Fox River	457.72	do	1889	do	
38	243.5	Ottawa—Fleming Farm	462.48	do	1900	do	
39	244.5	Marseilles—Douglas Farm	464.78	do	1883	do	
40	247.5	Marseilles (1¼ miles above dam)	484.31	do	'83–'89 '98–'00	do	
41	249.5	Marseilles—above Kickapoo Cr.	487.22	do	1900	do	
	247.5	Marseilles (city)	587.00	Down		Sanitary Dist.	San. Dist., Chicago.
	250.0	Marseilles (2 miles above)	587.26	do		Sanitary Dist.	
42	252.8	Seneca Bridge	484.50	Both	1900	U. S. Eng'rs	San. Dist., Chicago.
43	252.8	Seneca Bridge (200′ above)	587.28	Down	1903	U. S. Eng'rs	
	250.8	Seneca (2 miles below)	587.34	do		Sanitary Dist.	
	254.3	Seneca (1½ miles above)	587.24	do		do	
	256.8	Seneca (4 miles above)	587.24	do		do	
	260.8	Morris (2½ miles below)	587.08	do		do	
	262.8	Morris (½ mile below)	587.10	do		do	
	263.3	Morris Bridge	587.22	do		do	San. Dist., Chicago.
44	263.3	Morris Bridge	485.95	Both	'87, '93–'00 '03–'04	U. S. Eng'rs	United States Engineers, Peoria.
	265.5	Morris (2¼ miles above)	587.25	Down		Sanitary Dist.	
	266.8	Morris (3½ miles above)	587.04	do		do	
45	270.8	Divine—E. J. & E. Bridge	488.48	Up	1900	U. S. Eng'rs	
46	270.8	Divine—E. J. & E. Bridge	587.20	Down	'03–'04	Sanitary Dist.	San. Dist., Chicago.
	270.8	Divine—E. J. & E. Bridge	587.25	do		do	
47	273.3	Kankakee R. (¼ mi. above)	494.41	Both	1883	U. S. Eng'rs	
	273.1	Kankakee R. (800′ above)	587.36	Down		Sanitary Dist.	
48	274.0	Kankakee feeder	587.45	do	1904	do	San. Dist., Chicago.
49	275.0	Kankakee cut-off	587.16	do	1903	do	
	276.0	Kankakee cut-off (1 mi. above)	587.07	do		do	
50	277.0	Dupage R. (¾ mile below)	587.25	do	1904	do	San. Dist., Chicago.
	277.3	Dupage R. (mouth)	586.95	do		do	
	277.5	Smith's Bridge	587.17	Down		Sanitary Dist.	
51	278.0	Smith's Bridge (½ mi. above)	499.06	Both	'00, '03–'04	U. S. Eng'rs	United States Engineers, Peoria.
52	278.0	Smith's Bridge (½ mile above)	587.13	Down	'02–'04	Sanitary Dist.	San. Dist., Chicago.
	278.4	Jackson Cr. (2,000′ above)	587.10	do		do	
	279.8	Millsdale Highway Bridge	587.06	do		do	
	279.8	Millsdale Highway Bridge	587.06	do		do	
53	279.5	Foot of Treat's Island	500.41	Both	1883	U. S. Eng'rs	
54	280.0	Head of Treat's Island	509.55	do	1883	do	
	280.3	Head of Treat's Island	588.28	Down		Sanitary Dist.	
	284.0	Millsdale (2 miles above)	587.09	do		do	
	285.0	Patterson's Station	586.72	do		do	
	285.5	Brandon (below bridge)	584.55	do		do	
	285.8	Brandon Bridge	587.06	do		do	San. Dist., Chicago.
	287.0	So. Joliet—Davidson Stone Q.	587.04	do		do	

TABLE NO. 1—Concluded.



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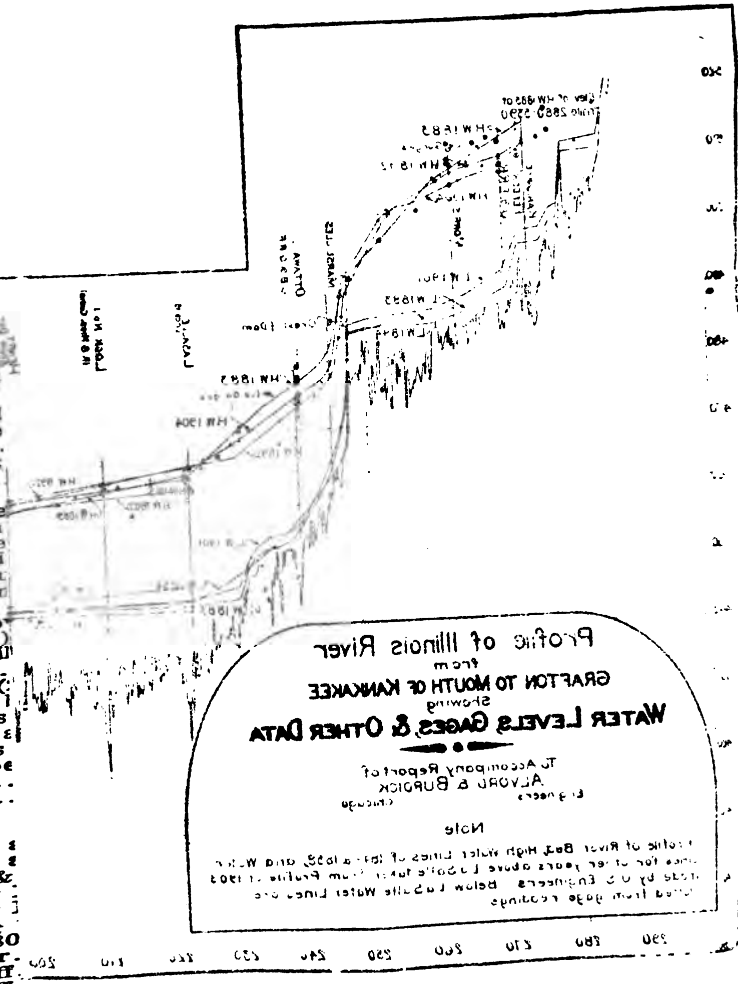
The diagrams, Fig. 3 indicate the average number of days in each year in which various gage heights are equalled or exceeded, and thus serve to show the prevalence and duration of various river stages. The

* 59th Congress Document No. 263.

TABLE NO. 1—Continued.

Number.	Miles above Grafton.	Genei						
	214.0	Marquette (1						
	218.3	Spring Valley						
	218.3	Spring Valley						
	220.8	Peru (1½ miles						
28	222.5	Peru Wagon]						
28	222.5	Peru Wagon]						
29	222.5	Peru Wagon]						
30	223.0	La Salle Lock						
30	224.0	La Salle High						
30	224.0	La Salle acque						
30	226.0	La Salle (2 mil						
31	230.0	Utica Highwa						
31	230.0	Utica Highwa						
32	234.7	Ottawa (below						
32	235.0	Buffalo Rock						
	236.0	Ottawa (3½ mil						
	237.5	Ottawa (2 mile						
	239.5	Ottawa—C., B.						
33	236.2	La Salle Count						
34	239.5	Ottawa—C. B.						
	239.5	Ottawa—C. B.						
35	239.6	Ottawa—betwe						
36	239.8	Ottawa Wagon						
37	240.0	Ottawa—above						
38	243.5	Ottawa—Flemi						
39	244.5	Marseilles—Dot						
40	247.5	Marseilles (1½ m						
41	249.5	Marseilles—abo						
	247.5	Marseilles (city)						
	250.0	Marseilles (2 mil						
42	252.8	Seneca Bridge						
43	252.8	Seneca Bridge (						
	250.8	Seneca (2 miles						
	254.3	Seneca (1½ miles						
	256.8	Seneca (4 miles						
	260.8	Morris (2½ miles						
	262.8	Morris (¼ mile be						
	263.3	Morris Bridge						
44	263.3	Morris Bridge						
	265.5	Morris (2½ miles						
	266.8	Morris (3½ miles						
45	270.8	Divine—E. J. &						
46	270.8	Divine—E. J. &						
	270.8	Divine—E. J. &						
47	273.3	Kankakee R. (½						
	273.1	Kankakee R. (80						
48	274.0	Kankakee feeder						
49	275.0	Kankakee cut-off						
	276.0	Kankakee cut-off						
50	277.0	Dupage R. (½ mile						
	277.3	Dupage R. (mout						
	277.5	Smith's Bridge						
51	278.0	Smith's Bridge (½						
52	278.0	Smith's Bridge (½						
	278.4	Jackson Cr. (2,000' above)	587.10	do.			do.	
	279.8	Millsdale Highway Bridge	587.06	do.			do.	
	279.8	Millsdale Highway Bridge	587.06	do.			do.	
53	279.5	Foot of Treat's Island	500.41	Both		1883	U. S. Eng'rs.	
54	280.0	Head of Treat's Island	509.55	do.		1883	do.	
	280.3	Head of Treat's Island	588.28	Down			Sanitary Dist.	
	284.0	Millsdale (2 miles above)	587.09	do.			do.	
	285.0	Patterson's Station	586.72	do.			do.	
	285.5	Brandon (below bridge)	584.55	do.			do.	San. Dist., Chicago.
	285.8	Brandon Bridge	587.06	do.			do.	
	287.0	So. Joliet—Davidson Stone Q.	587.04	do.			do.	



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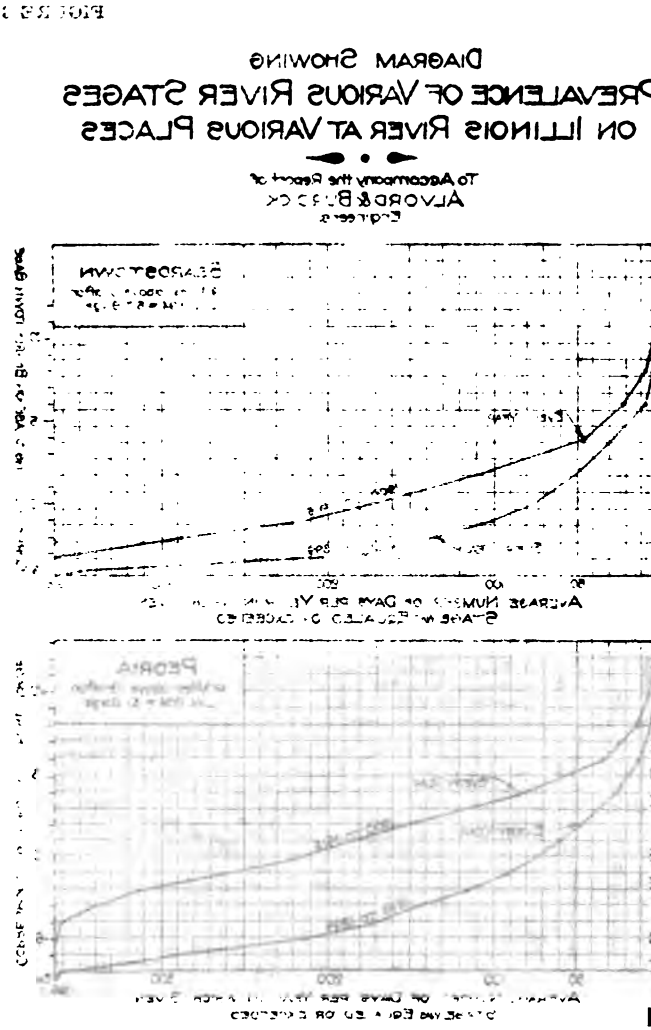

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28	222.5	Peru Wago:						
28	222.5	Peru Wago:						
29	222.5	Peru Wago:						
30	223.0	La Salle Lc						
30	224.0	La Salle Hi						
30	224.0	La Salle acc						
30	226.0	La Salle (2						
31	230.0	Utica High						
31	230.0	Utica High						
32	234.7	Ottawa (be						
32	235.0	Buffalo Ro						
	236.0	Ottawa (3½						
	237.5	Ottawa (2 r						
	239.5	Ottawa—C.						
33	236.2	La Salle Co						
34	239.5	Ottawa—C.						
	239.5	Ottawa—C.						
35	239.6	Ottawa—be						
36	239.8	Ottawa Wa						
37	240.0	Ottawa—at						
38	243.5	Ottawa—Fl						
39	244.5	Marseilles—						
40	247.5	Marseilles (						
41	249.5	Marseilles—						
	247.5	Marseilles (						
	250.0	Marseilles (						
42	252.8	Seneca Bric						
43	252.8	Seneca Bri						
	250.8	Seneca (2 m						
	254.3	Seneca (1½ r						
	256.8	Seneca (4 m						
	260.8	Morris (2½ r						
	262.8	Morris (¾ m						
	263.3	Morris Brid						
44	263.3	Morris Brid						
	265.5	Morris (2½ r						
	266.8	Morris (3½ r						
45	270.8	Divine—E.						
46	270.8	Divine—E.						
	270.8	Divine—E.						
47	273.3	Kankakee						
	273.1	Kankakee						
48	274.0	Kankakee f						
49	275.0	Kankakee c						
	276.0	Kankakee c						
50	277.0	Dupage R.						
	277.3	Dupage R.						
	277.5	Smith's Bri						
51	278.0	Smith's Bri						
52	278.0	Smith's Bri						
	278.4	Jackson Cr.						
	279.8	Millsdale H						
	279.8	Millsdale Highway Bridge	587.06	..do....			U. S. Eng'rs...	
53	279.5	Foot of Treat's Island	500.41	Both...		1883	..do	
54	280.0	Head of Treat's Island	509.55	..do....		1883	Sanitary Dist..	
	280.3	Head of Treat's Island	588.28	Down..			..do	
	284.0	Millsdale (2 miles above)	587.09	..do....			..do	
	285.0	Patterson's Station	586.72	..do....			..do	
	285.5	Brandon (below bridge)	584.55	..do....			..do	San. Dist., Chicago.
	285.8	Brandon Bridge	587.06	..do....			..do	
	287.0	So. Joliet—Davidson Stone Q.	587.04	..do....			..do	

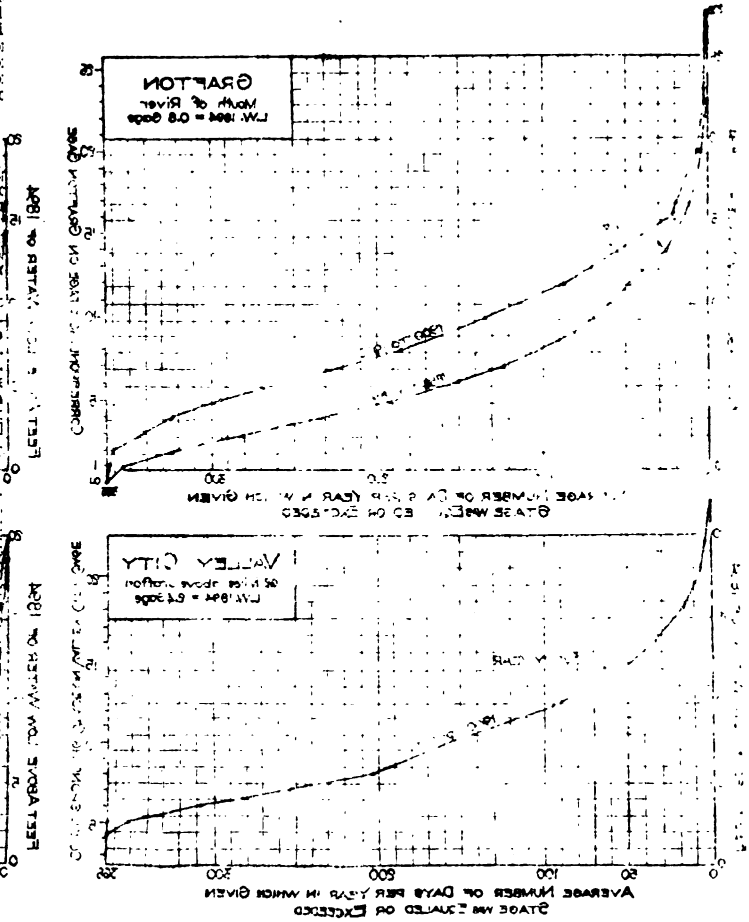

TABLE NO. 1—Concluded.

Number.	Miles above Grafton.	General location.	Elevation above Memphis datum.	Reads up or down.	Years covered by records.	By whom established.	Custodian of records.
	287.3	So. Joliet—above McDonough St.	586.86	Down		Sanitary Dist.	
	287.5	So. Joliet—McDonough St. Br.	587.07	do		do	
	287.6	So. Joliet—C. R. I. & P. R. R. Br.	587.03	do		do	
	288.8	Joliet—Dam No. 1	587.04	do		do	San. Dist., Chicago.
	290.0	Joliet—E. J. & E. Bridge	587.02	do		do	
55	.....	Joliet—below Adam's Dam	520.65	Both	1883	U. S. Eng'rs	
56	288.8	Joliet—below dam	544.65	do	'03–'04	Econ. L. & P. Co.	Econ. L. & Power Co., Joliet.
	288.8	Joliet—above dam	544.65	do	'01–'04	do	Econ. L. & Power Co., Joliet.
57	.....	Joliet—above Dam No. 1	543.76	do	'92–'98	Sanitary Dist.	
58	288.5	Joliet—Lock No. 5	538.23	do	'93–'04	Ill. Canal Com.	Illinois Canal Com., Lockport.
	292.0	Lockport (½ mile below)	587.18	Down		Sanitary Dist.	
59	292.8	Lockport	586.97	do	'00–'04	U. S. Eng'rs	San. Dist., Chicago.
	293.3	Lockport Controlling Works	587.04	do		Sanitary Dist.	San. Dist., Chicago.
	293.3	Lockport Controlling Works	586.97	do		do	San. Dist., Chicago.
	293.5	Lockport Controlling Works	590.08	do		do	San. Dist., Chicago.
60	308.0	Willow Springs	587.04	do	'90, '92–'98	do	San. Dist., Chicago.
61	314.0	Riverside	587.04	do	'86–'04	do	San. Dist., Chicago.
62	.....	Des Plaines Bridge	587.13	do	'87–'98	do	

NOTE.—Numbers in first column refer to gages listed in Appendix A22 of United States Engineers Report on 14-foot waterway.

The records of all gages except those maintained by the Sanitary District of Chicago (these refer particularly to the upper river) are printed in the Report of the U. S. Engineers on the "Fourteen Foot Waterway"*, and include all readings up to 1904 inclusive. For the purposes of this report, these gage records have been brought down to July, 1914. Space here prevents their reproduction in full, but numerous exhibits herewith attached give the result of the same in so far as they throw light upon the matters herein discussed. The complete gage records are on file at the office of the Rivers and Lakes Commission.

Fig. 2 shows a condensed profile of the river bed, and the extreme high and low water marks in various years.

Fig. 3 shows diagrammatically the prevalence of various gage heights at salient points upon the river, namely at Grafton, where the gage is on the Mississippi immediately below the mouth of the Illinois, and is therefore influenced not only by the Illinois, but principally by the larger watershed of the Mississippi; at Valley City about midway between the Kampsville and LaGrange dams, and near the head of the reach in which the levee operations have been most extensive; at Beardstown just below the junction of the Sangamon River, the largest tributary above the Illinois River mouth; and at the foot of Peoria Lake which is probably the best flow gaging station on the river.

The diagrams, Fig. 3 indicate the average number of days in each year in which various gage heights are equalled or exceeded, and thus serve to show the prevalence and duration of various river stages. The

* 59th Congress Document No. 263.

heights as shown at the left of the diagrams refer to feet above the low water of 1894, and at the right, the stage upon the local gage, the zeros of the gages being at various elevations in reference to low water and the Memphis datum plane. Two curves are shown for each place, namely, the average conditions from 1900 to 1913 inclusive, and from 1890 to 1899 inclusive, in order to visualize the effect of the increased flow of water since the opening of the Chicago Drainage Canal, January 1, 1900. It is apparent however, that a large part of the differences shown must be ascribed to differences in the natural run-off during these two periods, for the decade preceding 1900 is known to be one of relatively small natural flow. This is evidenced by the diagram referring to the Grafton gage on which the effect of the Illinois River flow is comparatively slight, which shows the prevalence of materially smaller gage heights prior to 1900 than subsequent thereto.

Excepting at Valley City, there has been no change in the river likely to materially affect gage heights during the period considered, except flow. The conditions for the decade previous to 1900 at Valley City are not shown, on account of the interruption in the record caused by the construction of the Kampsville dam completed in 1893. In order to obtain ten full years at Grafton, the years 1888 and 1889 were used on account of the interruption of the records for the years 1892 and 1893. In a few cases it was necessary to interpolate gage heights during the season of the year when the river was frozen over. It is believed in so doing, that the error is small. To have omitted the consideration of these evidently low water periods would have introduced serious error.

The gage at Beardstown, it is believed, typifies conditions generally throughout the river valley better than any other gage, it being just below the mouth of the Sangamon where the Illinois has received 83 per cent of its drainage, and a sufficient distance upstream so that the flow on the Illinois is major, and the influence of the Mississippi stage minor. At this place a 4-foot stage or more (10 feet on the Beardstown gage) has prevailed about half the time since 1900. Every year an 8-foot stage has been reached, and upon the average maintained for about forty-five days. A 12-foot stage has been exceeded twice. In the decade prior to 1900, a 1-foot stage was equalled or exceeded about half the time. A 2-foot stage (8 feet on Beardstown gage) was obtained every year for an average duration of 135 days.

An examination of the diagrams above referred to, further shows that considering the stages equalled or exceeded one-half the time, and comparing the periods of ten years prior and fourteen years subsequent to January 1, 1900, the Beardstown gage was 2.8 feet lower in the earlier period, the Peoria gage 5.5 feet lower, and the Grafton gage 3 feet lower. At extremely high water, and again at low water, the differences are less.

TYPICAL GAGE RECORDS.

As bearing upon prevailing stages in different years and different seasons in individual years, Fig. 4 is presented which shows a graph of the daily gage heights at Grafton since 1879, at La Grange both

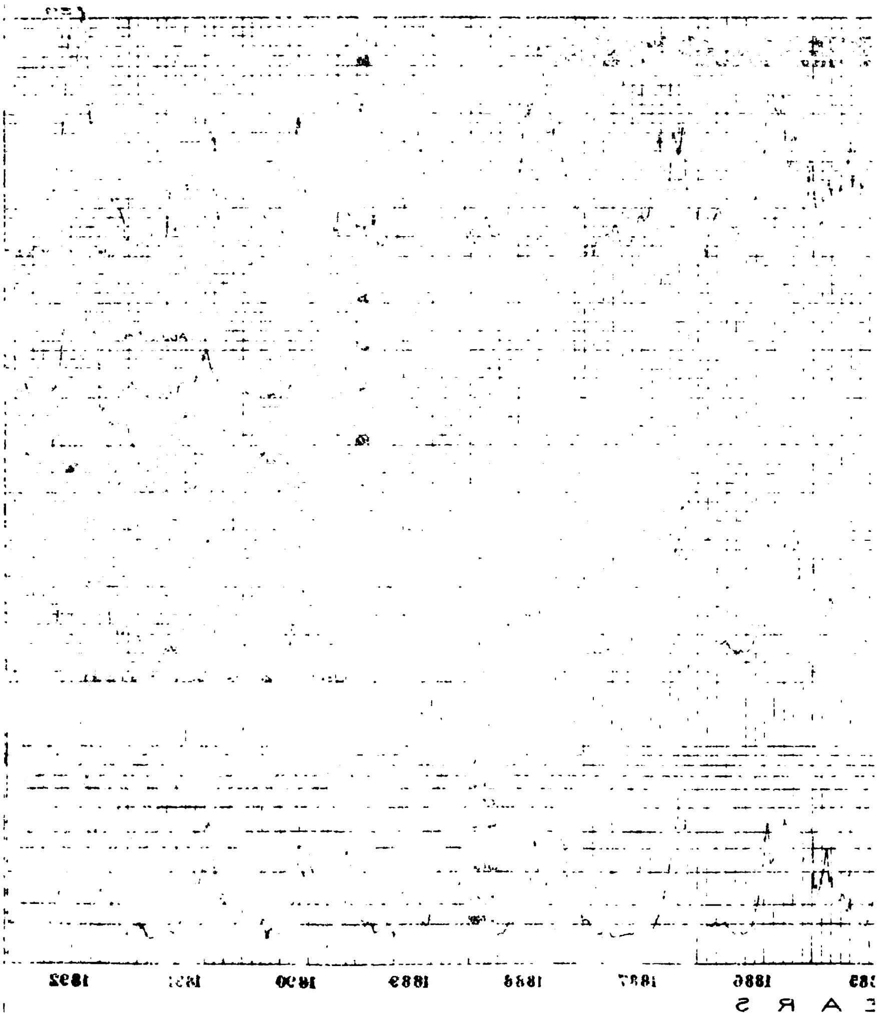

FIGURE 4 - Diagram of

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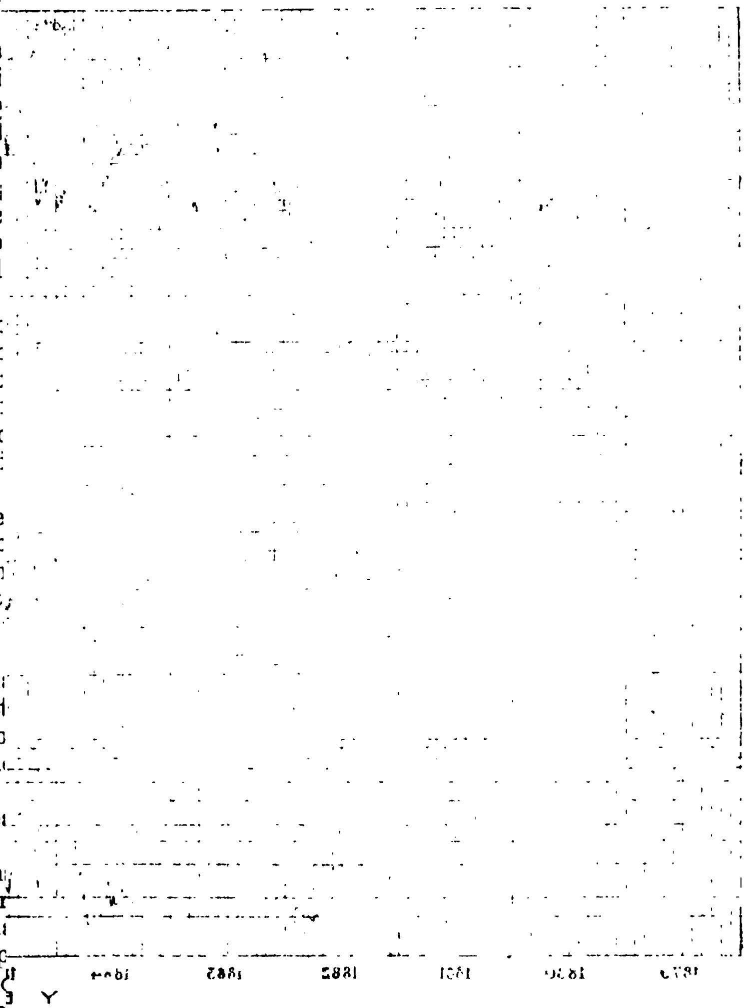

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immediately above and below the dam and lock since 1889, and at Peoria with some short interruptions of record since 1881. At the bottom of the diagram the approximate flow at Peoria is shown, based upon the Peoria rating curve, together with the flow of the Chicago Drainage Canal.

It will be noted that extremely low water at Grafton has varied only slightly since the establishment of the gage, reaching very nearly or quite to zero in the driest seasons up to and including the year 1914. The tailwater at La Grange, namely, immediately below the dam receded to between 7 and 8 feet in the dry years prior to 1900. It seems to have been little influenced by the construction of the Kampsville dam completed in 1893. Beginning with the year 1900, the tailwater has not fallen below 10 feet on the gage, and since 1901 it has not fallen below 11 feet. The headwater levels immediately above the dam likewise indicate increasing flows during the low water season since 1900.

The diagram for La Grange further shows the influence of flow upon the head created at the dam, the head reaching a maximum in the low water season, and nearly or quite disappearing in the spring flood months.

The headwater levels prior to 1899 were somewhat influenced by flashboards placed upon the crest of the dam, which increased the depth of water above the same. In 1894, flashboards were placed upon all four of the Illinois River dams. Flashboards were used more or less at LaGrange from 1890 to 1899, but have not since been used at that place.

NATURAL FLOW.

At the present time during dry seasons, the flow of the Illinois River is largely artificial by reason of the Lake Michigan water diverted to the river through the Chicago Drainage Canal. Prior to January 17, 1900, the conditions were natural except for the small amount of water pumped through the Illinois-Michigan Canal.

Table No. 2 shows the flow of the Illinois River at Peoria during each month of the years 1890 to 1900 inclusive, as estimated by Jacob A. Harman, C. E., and published in the report of the Illinois State Board of Health on Sanitary Investigations of the Illinois River tributaries in 1901. Table No. 3 is a summary of the years 1890 to 1899 inclusive, and a comparison thereof with the rainfalls in those years.

The flows are estimated from gage heights and a comparison thereof with seven measurements of flow at various stages of river ranging from 4 feet to 19 feet at the lower wagon bridge, Peoria. These figures probably represent a maximum estimate, as a greater number of subsequent measurements seems to indicate somewhat smaller flows, especially at the middle gage readings.

In reference to these figures, the following is quoted from Mr. Harman's report above referred to:

TABLE NO. 2—FLOW OF THE ILLINOIS RIVER AT PEORIA, ILLINOIS.

As estimated by Jacob A. Harman, C. E., Drainage area 13,480 square miles.

Month.	Discharge in second-feet.					Run-off.	
	Maximum.		Minimum.		Mean.	Depth—inches.	Second-feet—square mile.
	Gage.	Discharge.	Gage.	Discharge.			
1890							
January	12.3	20,329	6.2	4,706	12,201	1.025	.905
Februray	9.0	10,395	7.7	7,455	8,523	.712	.632
March	10.0	13,025	6.7	5,548	9,551	.802	.709
April	13.8	25,996	10.6	14,765	19,395	1.628	1.440
May	11.7	18,256	8.8	9,907	13,025	1.093	.966
June	13.3	24,034	8.9	10,150	17,103	1.436	1.268
July	11.6	17,923	3.0	992	6,950	.583	.515
August	3.3	1,221	3.0	992	1,066	.089	.078
September	3.6	1,474	3.2	1,221	1,303	.109	.096
October	4.9	2,854	2.6	723	1,800	.151	.133
November	4.6	2,494	3.6	1,474	1,950	.159	.144
December	4.4	2,268	3.8	1,657	1,850	.155	.136
Year	13.8	25,996	2.6	723	7,893	7.942	.588
1891							
January	4.9	2,854	3.8	1,657	2,193	.185	.162
February	8.6	9,433	3.9	1,752	2,793	.235	.206
March	10.0	13,025	6.7	5,548	8,808	.739	.653
April	15.0	30,985	10.3	13,880	22,649	1.903	1.682
May	12.8	22,140	4.9	2,854	9,988	.839	.741
June	8.9	10,150	4.8	2,732	5,906	.496	.437
July	7.1	6,275	3.3	1,221	2,612	.218	.194
August	3.9	1,752	3.1	1,066	1,286	.108	.094
September	3.4	1,303	3.0	992	1,055	.088	.077
October	3.0	992	2.7	786	892	.076	.067
November	5.0	2,980	2.9	921	1,737	.146	.128
December	5.9	4,233	4.7	2,612	3,549	.298	.262
Year	15.0	30,985	2.7	786	5,289	5.331	.392
1892							
January	5.8	4,080	4.7	2,612	3,108	.260	.229
February	7.1	6,275	4.7	2,612	4,335	.364	.321
March	8.5	9,201	7.0	6,089	7,763	.652	.575
April	14.5	28,858	8.1	8,303	20,517	1.722	1.521
May	21.9	69,031	10.9	15,678	46,342	3.889	3.440
June	18.5	48,130	14.4	28,441	35,977	3.020	2.672
July	17.5	42,745	10.0	13,025	27,615	2.318	2.032
August	9.9	12,746	4.4	2,268	5,725	.481	.425
September	4.7	2,612	4.2	2,054	2,302	.193	.170
October	4.4	2,268	4.0	1,850	1,980	.165	.147
November	4.8	2,732	4.0	1,850	2,202	.185	.165
December	5.3	3,372	4.5	2,380	2,885	.241	.212
Year	21.9	69,031	4.0	1,850	13,396	13.490	.994
1893							
January	4.7	2,612	4.1	1,950	2,214	.186	.164
February	13.8	25,996	4.3	2,160	11,721	.984	.869
March	19.6	54,570	13.2	23,649	37,296	3.132	2.768
April	15.5	33,175	11.6	17,923	24,571	2.064	1.823
May	16.5	37,771	11.9	18,934	29,068	2.440	2.176
June	11.7	18,256	8.3	8,745	14,914	1.254	1.107
July	7.9	7,874	3.6	1,474	3,464	.291	.275
August	3.6	1,474	3.0	992	1,362	.115	.101
September	3.6	1,474	3.0	992	1,156	.107	.084
October	4.0	1,850	3.5	1,387	1,752	.147	.129
November	4.1	1,950	3.8	1,657	1,765	.148	.130
December	5.0	2,980	4.0	1,850	2,272	.191	.168
Year	19.6	54,570	3.0	992	10,966	11.060	.815
1894							
January	5.9	4,233	4.9	2,854	3,372	.288	.256
February	6.3	4,868	5.4	3,509	4,107	.344	.301
March	12.0	19,277	6.0	4,390	13,592	1.141	1.008
April	9.0	10,395	7.4	6,851	7,905	.664	.586
May	9.2	10,894	6.8	5,725	8,413	.706	.624

TABLE NO. 2—Continued.

Month.	Discharge in second-feet.					Run-off.	
	Maximum		Minimum.		Mean.	Depth—inches.	Second-feet—square mile.
	Gage.	Dis-charge.	Gage.	Dis-charge.			
June	7.2	6,464	4.4	2,268	3,481	.293	.258
July	4.3	2,160	3.4	1,303	1,657	.139	.122
August	3.5	1,387	3.1	1,066	1,208	.101	.088
September	6.4	5,034	3.2	1,142	3,283	.275	.242
October	4.9	2,854	3.8	1,657	1,825	.153	.135
November	4.3	2,160	3.8	1,657	2,059	.173	.152
December	5.1	3,108	4.3	2,160	2,495	.210	.185
Year	12.0	19,277	3.1	1,066	4,460	4.487	.331
1895							
January	4.7	2,612	3.3	1,221	1,502	.126	.111
February	6.7	5,548	3.5	1,387	2,160	.182	.160
March	8.0	8,087	5.8	4,082	5,998	.504	.445
April	7.3	6,656	5.2	3,239	5,008	.420	.371
May	5.0	2,980	3.9	1,752	2,437	.205	.181
June	3.9	1,752	3.1	1,066	1,387	.116	.102
July	6.3	4,868	3.7	1,564	2,624	.220	.194
August	5.3	3,372	3.4	1,303	1,834	.153	.134
September	5.5	3,648	3.6	1,474	2,450	.206	.181
October	4.1	1,950	3.6	1,387	1,590	.135	.115
November	4.6	2,494	3.7	1,564	2,059	.172	.151
December	14.9	30,554	4.3	2,160	11,022	.925	.817
Year	14.9	30,554	3.1	1,066	3,338	3.364	.247
1896							
January	14.3	28,027	8.2	8,523	15,555	1.306	1.153
February	11.1	16,303	8.1	8,303	11,257	.945	.834
March	11.9	18,934	8.3	8,745	13,767	1.156	1.020
April	8.4	8,971	6.6	5,373	6,999	.588	.519
May	10.2	13,592	5.3	3,372	7,124	.598	.526
June	10.0	13,025	5.8	4,082	7,585	.636	.561
July	9.2	10,894	3.6	1,474	3,524	.296	.261
August	9.7	12,201	6.7	5,548	8,390	.705	.624
September	6.6	5,373	5.4	3,509	4,148	.349	.308
October	8.9	10,150	5.8	4,082	7,029	.590	.521
November	8.1	8,303	5.8	4,082	6,464	.543	.480
December	7.4	6,851	5.4	3,509	5,350	.449	.396
Year	14.3	28,027	3.6	1,474	8,099	8.161	.600
1897							
January	14.9	30,554	5.4	3,509	22,786	1.912	1.689
February	13.8	25,996	10.6	14,765	18,738	1.574	1.390
March	18.3	47,019	12.6	21,408	34,527	2.900	2.560
April	17.3	4,720	11.2	16,621	25,231	2.119	1.852
May	11.5	17,592	6.8	5,725	12,540	1.053	.930
June	9.6	11,933	4.5	2,380	5,666	.475	.419
July	9.1	10,643	4.9	2,854	5,607	.473	.417
August	4.7	2,612	3.8	1,657	1,852	.155	.136
September	3.9	1,752	3.7	1,564	1,734	.146	.128
October	3.8	1,657	3.7	1,564	1,549	.128	.113
November	4.9	2,854	3.8	1,657	2,115	.177	.156
December	4.4	2,268	4.1	1,950	1,734	.146	.128
Year	18.3	47,019	3.7	1,564	11,173	11.258	.826
1898							
January	7.7	7,455	4.0	1,850	3,845	.322	.285
February	13.4	24,421	6.9	5,906	15,180	1.275	1.126
March	19.3	52,766	11.6	17,923	31,643	2.658	2.346
April	19.2	52,169	10.9	15,678	29,468	2.476	2.186
May	14.1	27,206	8.8	9,907	17,275	1.451	1.281
June	13.5	24,810	8.8	9,907	15,935	1.339	1.182
July	9.1	10,643	3.5	1,387	4,259	.357	.315
August	5.7	3,935	4.0	1,850	2,678	.225	.198
September	5.8	4,082	4.4	2,268	3,372	.283	.249
October	8.0	8,087	4.7	2,612	3,762	.315	.278
November	10.0	13,025	7.2	6,464	9,559	.800	.707
December	8.4	8,971	5.9	4,233	6,102	.512	.451
Year	19.3	52,766	3.5	1,387	11,923	12.013	.884

TABLE NO. 2—Concluded.

Month.	Discharge in second-feet.					Run-off.	
	Maximum.		Minimum.		Mean.	Depth—inches.	Second-feet—square mile.
	Gage.	Discharge.	Gage.	Discharge.			
1899							
January	9.3	11,149	7.5	7,049	9,641	.809	.715
February	10.6	14,765	5.3	3,372	6,264	.526	.464
March	15.1	31,417	11.4	17,265	27,308	2.294	2.026
April	13.0	22,889	9.0	10,395	17,730	1.490	1.318
May	8.7	9,669	6.7	5,548	7,100	.596	.526
June	8.7	9,669	4.1	1,950	5,954	.500	.442
July	6.2	4,706	3.8	1,657	2,888	.241	.212
August	4.4	2,268	3.4	1,303	1,678	.141	.124
September	4.3	2,160	3.7	1,564	1,813	.153	.134
October	4.6	2,494	4.0	1,850	2,054	.172	.152
November	5.1	3,108	4.4	2,268	2,660	.224	.196
December	6.8	5,725	4.5	2,380	3,448	.290	.259
Year	15.1	31,417	3.4	1,303	7,378	7.436	.547
1900							
January	8.1	8,303	4.9	2,874	4,924	.416	.365
February	12.4	20,686	7.5	7,049	14,500	1.218	1.076
March	19.9	56,401	11.3	16,941	35,100	2.948	2.604
April	16.9	39,717	11.9	18,934	29,110	2.444	2.160
May	11.5	17,592	8.6	9,433	12,036	1.011	.893
June	8.9	10,150	6.8	5,725	8,093	.677	.597
July	7.3	6,656	6.3	4,868	5,590	.470	.416
August	8.1	8,303	6.7	5,548	7,149	.601	.530
September	8.2	8,523	5.3	3,372	5,666	.476	.420
October	7.0	6,089	6.3	4,868	5,382	.452	.399
November	9.5	11,668	6.7	5,548	7,071	.594	.525
December	9.7	12,201	8.0	8,087	9,688	.814	.718
Year	19.9	56,401	4.9	2,874	12,026	12.121	.892

TABLE NO. 3—SUMMARIZED FLOW OF ILLINOIS RIVER AT PEORIA.

By Jacob A. Harman, C. E.

Year.	Run-off inches.	Rainfall —inches.	Per cent running off.	Cubic feet per second.	Second-feet per-square mile.
1890	7.942	33.79	23.6	7,893	.588
1891	5.331	32.30	16.5	5,289	.392
1892	13.555	40.54	33.4	13,396	.994
1893	11.060	28.80	28.4	10,966	.815
1894	4,487	28.72	15.6	4,460	.331
1895	3.364	29.81	11.3	3,338	.247
1896	8.161	36.03	22.6	8,099	.600
1897	11.258	32.63	34.5	11,173	.826
1898	12.013	41.49	29.0	11,923	.884
1899	7.436	31.11	23.9	7,378	.547
Averages	8.460	33.52	25.2	8,391	.622
Without flow from Illinois and Michigan Canal	7.860	33.52	23.9	7,791	.576

"The period under discussion (1890-1899) has been one of low rainfall, the average for the ten years having been 33.52″, while the normal rainfall for Illinois as given by Leverett in Water Resources of Illinois is 37.85″, an average annual shortage of 4.33″. During that time the rainfall exceeded the normal only two years, namely, 1892 and 1898, the intervening years being regarded as the greatest period of severe drouth that has been experienced in this region since it has been settled." * * *

"The actual low water flow at Peoria during the last ten years has for days and sometimes weeks been as low as 1,000 to 1,200 cubic feet per second,

approximately 600 cubic feet of which has been furnished to the Illinois-Michigan Canal by the pumps at Bridgeport. * * * The natural flow of the Illinois River at Peoria has apparently been as low as 200 to 300 cubic feet per second."

U. S. GEOLOGICAL SURVEY MEASUREMENTS AT PEORIA.

During the years 1903, 1904, 1905, and 1906, the U. S. Geological Survey maintained a gaging station at the Peoria and Pekin Railway bridge one and one-half miles southwest of Peoria. Table No. 4 summarizes the flow as reported in Water Supply Papers Nos. 98, 171 and 207. Flows are given for the open water months only. During the years of observation, the Drainage Canal being in operation, the flow on no day was less than 6,170 second-feet.

TABLE NO. 4—ESTIMATED MONTHLY DISCHARGE OF THE ILLINOIS RIVER AT PEORIA, ILLINOIS—DRAINAGE AREA 13,250 SQUARE MILES.

Made by U. S. Geological Survey and reported in Water Supply Papers Nos. 98, 171 and 207.

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1903					
March 10-31	....	....	40,589	3.06	2.50
April	44,090	22,830	31,169	2.35	2.62
May	25,360	11,230	17,332	1.31	1.51
June	14,870	8,000	10,152	.77	.86
July 1-8	....	....	9,160	.69	.21
August 22-31	....	....	8,637	.65	.24
September	16,065	8,620	12,127	.92	1.03
October	14,080	11,565	13,129	.99	1.14
November	11,420	7,850	9,790	.74	.83
December	11,420	8,460	9,500	.72	.83
1904					
March 21-31	57,650	37,650	51,330	.387	1.58
April	54,950	26,440	39,000	2.94	3,28
May	28,410	13,910	19,310	1.46	1.68
June	13,910	7,713	11,000	.830	.926
July	8,572	7,118	7,789	.588	.678
August	8,092	7,008	7,577	.572	.660
September	9,614	6,860	7,531	.568	.634
October	9,822	7,491	8,508	.642	.740
November	7,450	7,156	7,333	.553	.617
December 1-12	7,400	7,080	7,186	.542	.242
1905					
April	20,480	16,820	18,760	1.42	1.58
May	35,500	16,820	24,580	1.86	2.14
June	22,930	14,460	19,320	1.46	1.63
July	13,740	8,044	10,490	.792	.913
August	8,092	7,575	7,875	.594	.685
September	10,125	7,659	9,134	.689	.769
October	8,044	7,008	7,587	.573	.661
November	8,044	6,900	7,473	.564	.629
December	8,355	7,491	7,851	.593	.684
1906					
January	19,800	8,460	11,500	0.871	1.00
February	24,800	16,000	18,700	1.42	1.48
March	27,000	18,700	23,600	1.79	2.06
April	25,500	17,100	22,700	1.72	1.92
May	16,300	9,220	12,000	.909	1.05
June	9,280	7,360	8,350	.633	.71
July 1-21	7,360	6,170	6,620	.502	.39

FLOW OF TRIBUTARIES.

Mr. Harman further summarizes the available records of flow on the Des Plaines, a northern tributary of the Illinois, and compares it with the rainfall from 1887 to 1898, as shown on Table No. 5 herewith. Table No. 6 is also presented, comparing the flow on the Des Plaines with that of the Illinois where the records overlap. It indicates that the average conditions upon the two rivers are quite similar as regards aggregate run-off.

TABLE NO. 5—FLOW OF THE DES PLAINES RIVER BASIN ABOVE RIVERSIDE.

From report of Illinois State Board of Health, Jacob A. Harman, C. E.

Year.	Off—inches.	On—inches.	Per cent of rain running-off.	Second-feet per square mile.
1887	13.18	29.13	45.2	1.00
1889	6.13	34.95	17.6	0.45
1893	10.38	29.03	35.8	0.76
1894	7.44	27.80	26.8	0.55
1895	3.08	30.48	10.1	0.23
1896	5.04	33.74	15.0	0.38
1897	14.05	30.55	46.0	1.03
1898	10.92	37.74	29.0	0.81
Averages	8.777	31.68	27.7	0.65

TABLE NO. 6—COMPARISON OF RUN-OFF ON DES PLAINES AND ILLINOIS RIVERS.

From report of Illinois State Board of Health, Jacob A. Harman, C. E.

Year.	Depth in inches.			Second-feet per square mile.		
	Des Plaines.	Illinois.	Illinois less canal.	Des Plaines.	Illinois.	Illinois less canal.
1893	10.38	11.06	10.46	0.76	0.815	0.769
1894	7.44	4.49	3.89	0.55	.331	.285
1895	3.08	3.36	2.76	0.23	.247	.201
1896	5.04	8.16	7.56	0.38	.600	.554
1897	14.05	11.26	10.66	1.03	.826	.780
1898	10.92	12.01	11.41	0.81	.884	.838
Averages	8.48	8.39	7.79	0.63	0.617	0.571

MISCELLANEOUS ILLINOIS STREAMS.

Table No. 7 is published by the Illinois State Water Survey, Series No. 11, Year 1914. It is a summary of the flow records obtained on Illinois streams by the State of Illinois in cooperation with the U. S. Geological Survey during the years 1905 to 1911, and a comparison of the flows with the rainfalls prevailing during the time of flow measurements. These streams with a few exceptions, are tributaries of the Illinois River and are all on or adjacent to this watershed. The aggregate average flows of these streams for the period considered is as

shown—.82 second-feet per square mile of drainage area, which is equivalent to 10.9″ of watershed depth per year, as compared to 7.86″ for the Illinois River at Peoria for the period 1890 to 1899; likewise upon the tributaries, 28.8 per cent of the rain that fell ran off through the streams as measured, as compared to 23.4 per cent upon the Illinois during the decade 1890 to 1899.

TABLE NO. 7—SUMMARY OF RAINFALL AND RUN-OFF DATA IN ILLINOIS.

Illinois State Water Survey—No. 11.

Stream and location of gaging station.	Watershed area—square miles.	Dates of gagings.	Duration of gagings—months.	Rainfall—(monthly average).			Run-off.					
				During gaging period—inches.	Normal for the period—inches.	Per cent departure from normal.	Average second-feet on watershed.	Maximum second-feet.	Minimum second-feet.	Mean second-feet.	Average second-feet per square mile.	Per cent of rainfall.
Rock River at Rockton......	6150	1903–09	67	3.01	2.85	+ 5.6	16550	27100	950	4790	0.78	28.9
Fox River at Sheridan.......	2170	1905–06	9	2.97	3.02	— 1.65	5700	9780	240	1810	.83	31.8
Kankakee River at Momence	2430	1905–06	17	3.12	2.96	+ 5.4	6780	6960	360	1980	.81	29.2
Big Muddy River at Cambon	735	1908–11	37	3.48	3.37	+ 3.27	2290	11000	......	536	.73	23.4
Beaucoup Creek at Pinckneyville.....................	227	1908–11	37	3.37	3.11	+ 8.4	685	2170	......	98	.43	14.3
Embarrass River at Oakland.	535	1909–11	21	3.08	2.99	+ 3.0	1470	3650	3	458	.86	31.0
Embarrass River at St. Marie	1540	1909–11	21	3.18	3.25	— 2.2	4390	6210	100	1290	.84	29.4
Kaskaskia River at Arcola...	390	1908–11	39	3.08	2.99	+ 3.0	1070	3870	......	378	.97	35.3
Kaskaskia River at Shelbyville.....................	1030	1908–11	41	3.37	3.27	+ 3.1	3100	10600	5.5	948	.92	30.6
Kaskaskia River at Vandalia	1980	1908–11	40	3.40	3.22	+ 5.6	6030	17720	3.5	1357	.69	22.5
Kaskaskia River at Carlyle..	2680	1908–11	40	3.49	3.26	+ 7.1	8380	19900	23	2213	.83	26.6
Kaskaskia River at New Athens..................	5220	1907–11	54	3.75	3.39	+10.0	17500	54400	162	5650	1.08	32.3
Shoal Creek at Breese........	760	1909–11	20	3.48	3.52	— 1.1	2370	6620	48	641	.84	27.0
Silver Creek at Lebanon.....	335	1908–11	36	3.75	3.39	+10.1	1100	4030	......	293	.88	26.6
Skillet Fork, Little Wabash at Wayne City...............	481	1908–11	35	3.26	3.47	— 6.1	1400	7760	.2	357	.75	25.6
Sangamon River at Monticello	550	1908–11	41	2.98	3.05	— 2.3	1470	9280	1.6	482	.88	32.8
Sangamon River at Riverton	2560	1908–11	41	3.17	3.21	— 1.3	7250	19200	60	2040	.80	28.1
Sangamon River at Oakford..	5000	1909–11	16	2.97	3.09	— 3.9	13300	11000	432	3240	,65	24.4
South Fork Sangamon River at Taylorville..............	427	1908–11	41	3.27	3.37	— 2.96	1250	4140	5	340	.80	27.2
Salt Creek at Kenney........	459	1908–11	40	2.94	3.01	— 2.3	1210	5840	1	334	.73	27.6
Total....................	35659	....	....	....	....	....	103295	......	......	29235	.....	....
Average.................	......	....	....	....	....	....	......	......	......	......	0.82	28.8

NORMAL RAINFALL OF ILLINOIS.

Fig. 5 is a map indicating the normal variations in rainfall in the State of Illinois taken from the Illinois State Water Survey Series No. 11, Year, 1914. It shows the progressively increasing rainfall from the northern to the southern end of the State, the upper watershed of the Illinois lying within a region having a normal rainfall of 30 to 35 inches, the lower one-half of the watershed lying in territory where the normal rainfall lies between 35 and 40 inches. It has been noted that in the larger floods upon the Illinois River, the higher rainfall rates for the days on which the floods were produced, progressively increased toward the southeastern side of the watershed.

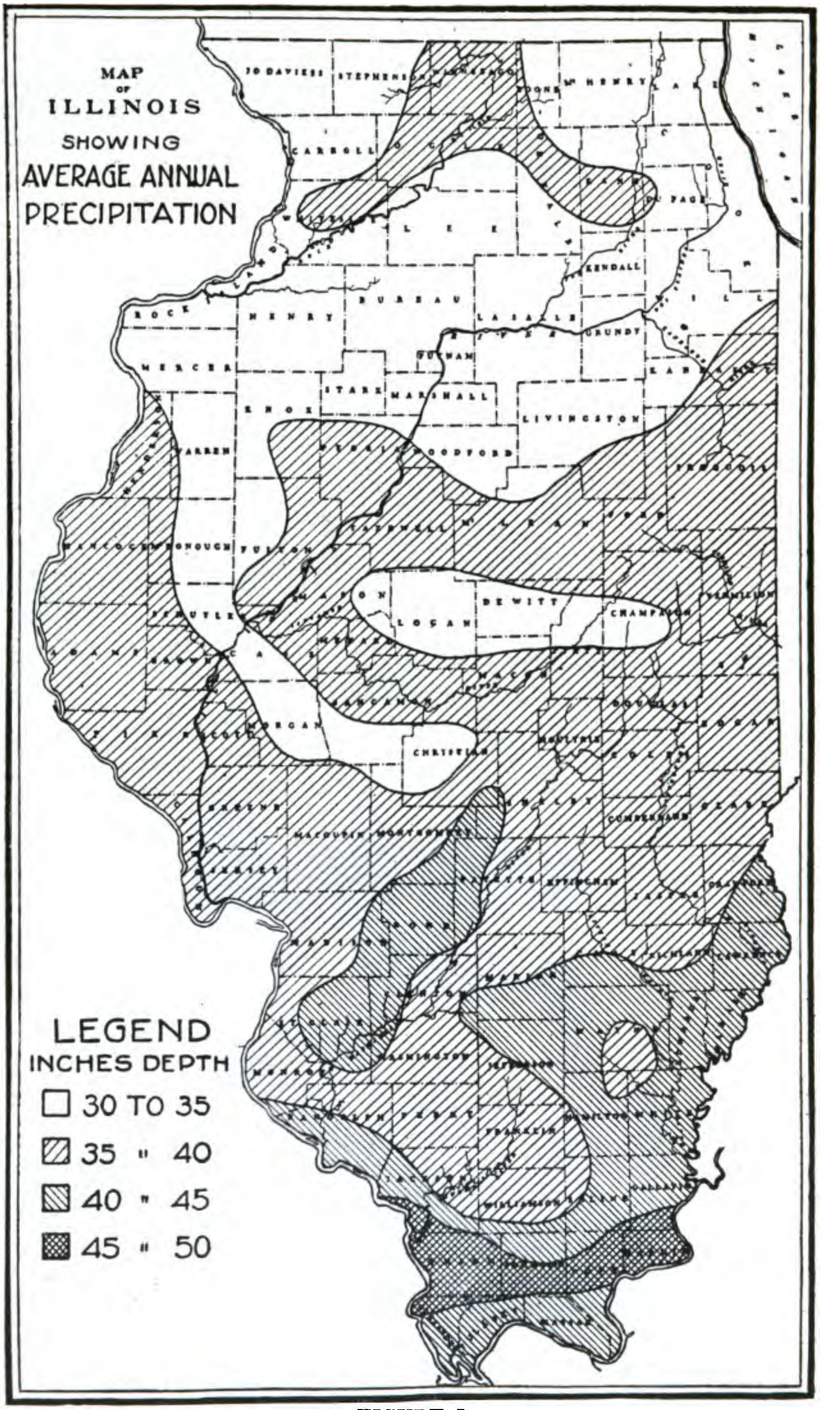

MAP
OF
ILLINOIS
SHOWING
AVERAGE ANNUAL
PRECIPITATION
LEGEND
INCHES DEPTH
30 TO 35
35 " 40
40 " 45
45 " 50

FIGURE 5.

FLOW OF THE CHICAGO DRAINAGE CANAL.

Since 1848 the natural flow of the Illinois River has received some artificial replenishment by Lake Michigan water at Chicago—prior to January 17, 1900, through the operation of pumps at Chicago, for the water supply of the Illinois-Michigan Canal, and in the later years of that period, to promote the cleanliness of the Chicago River. Although the supply thus pumped was nearly or quite equal to the extreme low water flow of the Illinois River so far south as Peoria, the accession of water from this source was small compared to the aggregate annual flow of the river. Mr. Harman estimates the flow from the Illinois-Michigan Canal at 600 cubic feet per second for the 10-year period previous to 1900. This is equivalent to .6 of an inch per year on the watershed above Peoria, or about 7 per cent of the average flow of the river at that place during the decade stated.

Since January 17, 1900, the previous water conditions have been greatly changed through the flow of the Chicago Drainage Canal, which has averaged from 3,136 second-feet in 1900 to 7,185 second-feet in 1913. The flow in the last named year is equivalent to 7.1″ on the drainage area tributary to Peoria, which is about 87 per cent of the estimated average flow at that place during the decade immediately prior to the opening of the canal. It is equivalent to about 3.4″ upon the watershed tributary to the mouth of the river; probably equivalent to about 40 per cent of the run-off of the prior decade at that place.

TABLE NO. 8—FLOW OF THE CHICAGO DRAINAGE CANAL, 1900 TO 1914.
Data from report on removal of navigation dams by L. E. Cooley—cubic feet per second.

Months.	1900	1901	1902	1903	1904	1905	1906	1907
January	1,450	4,917	4,194	6,124	5,463	5,167	4,457	5,303
February	2,315	5,060	4,204	5,750	5,170	5,527	4,626	5,467
March	2,100	5,296	4,233	5,361	4,708	5,546	4,393	4,954
April	2,728	4,427	4,165	4,638	4,946	4,737	4,507	4,954
May	3,228	3,106	4,166	4,570	5,125	4,120	4,719	5,031
June	3,226	2,903	4,071	4,812	4,100	4,124	4,420	5,539
July	3,391	3,140	4,323	4,870	4,553	4,123	3,996	5,600
August	3,576	3,932	4,204	4,532	4,573	4,290	3,429	6,250
September	2,307	3,906	4,291	4,330	4,141	4,340	3,740	4,703
October	3,450	3,840	4,155	4,545	4,004	4,510	5,221	4,205
November	3,813	3,896	4,248	4,686	4,451	3,378	5,198	4,395
December	4,227	4,114	5,352	5,570	5,067	3,919	4,907	5,005
Mean	2,989	4,041	4,302	4,971	4,693	4,477	4,471	5,117

TABLE NO. 8—Concluded.

Months.	1908	1909	1910	1911	1912	1913	1914
January	....	....	....	5,720	5,782	6,253	6,653
February	....	....	....	5,770	5,525	6,074	6,647
March	....	....	....	5,565	5,681	5,947	6,235
April	....	....	....	5,675	6,340	6,238	6,550
May	....	....	....	5,837	5,875	7,222	7,297
June	....	....	....	6,686	6,363	7,684	7,425
July	....	....	....	7,146	6,949	7,850	....
August	....	....	....	6,927	7,142	8,390	....
September	....	....	....	7,093	7,189	8,381	....
October	....	....	6,660	7,385	7,060	7,943	....
November	....	....	6,490	7,113	6,857	7,272	....
December	....	....	5,512	6,542	6,298	7,075	....
Mean	5,317	5,667	5,967	6,454	6,378	7,193	....

Table No. 8 is a statement of the average flow of the Chicago Drainage Canal in each month up to June, 1914, as stated in the report of Mr. Lyman E. Cooley, C. E., on the "Removal of the Navigation Dams of the Illinois River." The monthly flows are lacking for the years 1908 and 1909, and a part of 1910. The same information is shown diagrammatically upon Fig. 4 at the bottom of the diagram. It will be observed that the flow has gradually increased during the fifteen years that the canal has been operated. In the respective years the flow is nearly constant, but lately has been slightly greater in the late summer months than the normal for the respective years. This probably arises from the desirability of greater dilution at the season when the sewage nuisance is likely to be most objectionable.

EFFECT ON LOW WATER CONDITIONS.

The natural run-off of the Illinois Basin occurs principally in the spring and early summer, whereas the water of the Drainage Canal is nearly uniformly distributed throughout the year. As would be expected, therefore, the low water conditions are the ones most markedly changed through the accession of the Lake Michigan water. It has been estimated that prior to 1900, there were periods when the flow at Peoria was as low as 1,000 to 1,200 second-feet. The flows less than 2,000 second-feet were the rule rather than the exception for periods of from one to three months during the summer and fall. Fig. 4 illustrates graphically the changed conditions both in gage height and flow at Peoria, largely brought about through the accession of this additional water. Where gage heights at Peoria as low as 3 feet, frequently occurred prior to 1900, the lowest gage heights since 1901 have been 7 or 8 feet, and within the past three years, not less than 9 feet. A part of this increase may have been due to greater natural flow.

The additional water further shows its effect in less degree at other gages downstream, but has apparently practically lost its effect when Grafton is reached, for the lower water stages at Grafton have been substantially the same of late years as previously. Fig. 4 illustrates these effects at Peoria, the La Grange Dam, and Grafton.

FUTURE DELIVERY OF DRAINAGE CANAL.

The main channel of the Sanitary District has an estimated capacity of 14,000 second-feet, except for about one-quarter of its length, between Summit and Robey Street, which is subject to progressive enlargement. The original capacity of this section was about 8,500 second-feet, but is now undergoing enlargement. The Chicago River is being improved to produce 10,000 second-feet. With the Sag Channel tapping the Calumet River completed, also improvements now under way, it will be practicable to deliver about 14,000 second-feet to the Des Plaines River.

The Secretary of War by virtue of the Act of March 3, 1899, refused to permit more than 4,167 second-feet to be drawn from the lake at Chicago, and in 1912, enjoined the Sanitary District from withdrawing a greater volume. The issues of this case are now in court.

The State law under which the Sanitary District was organized requires that the sewage of the district shall be diluted with lake water at a rate equivalent to 3,333 second-feet for each million of population

FIGURE 5A.

LaGrange Lock and Dam.

in the district. The total population of the Sanitary District by U. S. Census 1910, was 2,311,810. A compliance with this provision in the law would require a flow of about 7,700 second-feet.

NAVIGATION DAMS.

The Illinois River has been a highway of commerce from the earliest settlement of the country. For the purpose of maintaining low water, navigation dams and locks have been constructed at Kampsville, La Grange, Copperas Creek and Henry in the early days producing slack water navigation as far up the river as La Salle, the terminus of the Illinois-Michigan Canal. The dams at Henry and Copperas Creek were completed in 1871 and 1877 respectively, and were constructed by the State of Illinois. The dam at La Grange was completed in 1889, and the dam at Kampsville in 1893. These two dams were built by the U. S. Government. Table No. 9 shows some salient facts relating to these dams. Their locations are shown upon Fig. 6. They are also shown on several other maps.

TABLE NO. 9—DATA OF ILLINOIS RIVER NAVIGATION DAMS.

	Kampsville.	La Grange.	Copperas Creek.	Henry.
Miles above Grafton	31	77	137	196
Year completed	1893	1899	1877	1871
Crest level Memphis datum	*421.9	432.63	*439.0	*443.1
Length of crest between abutments—feet	1,200	819	640	540
Head created under various water conditions, i. e. difference in water level immediately above and below dam and locks—feet—				
Low water of 1894	8.93	7.45	4.28	5.19
Low water of 1901	6.14	5.60	2.38	2.80
Usual head at low water season past 5 years	2.6 to 4.0	3.2 to 4.2	0.3 to 0.6	0.6 to 1.2
Usual head during high water months	0.0 to 0.2	0.0 to 0.8	....	....

* 423.9 prior to 1904. Several changes between 1904 and 1906.
By scale profile of 1904 Survey U. S. Engineers.

Under the water conditions prevailing at the time of their construction, these dams added materially to the navigability of the stream. Thus, during the low water season of 1894, the heads created, or increased water depth at each dam were as follows:

	Feet.
Kampsville	8.93
La Grange	7.45
Copperas Creek	4.28
Henry	5.19

In the low water season of 1901 (the lowest water since the opening of the Chicago Drainage Canal), the heads at the several dams were as follows:

Kampsville	6.14
La Grange	5.60
Copperas Creek	2.38
Henry	2.80

The lowest water occurred between July 25th and August 18th, when the flow of the Chicago Drainage Canal was 3,140 second-feet in July, and 3,932 second-feet in August. This is about one-half the flow of the canal in 1913.

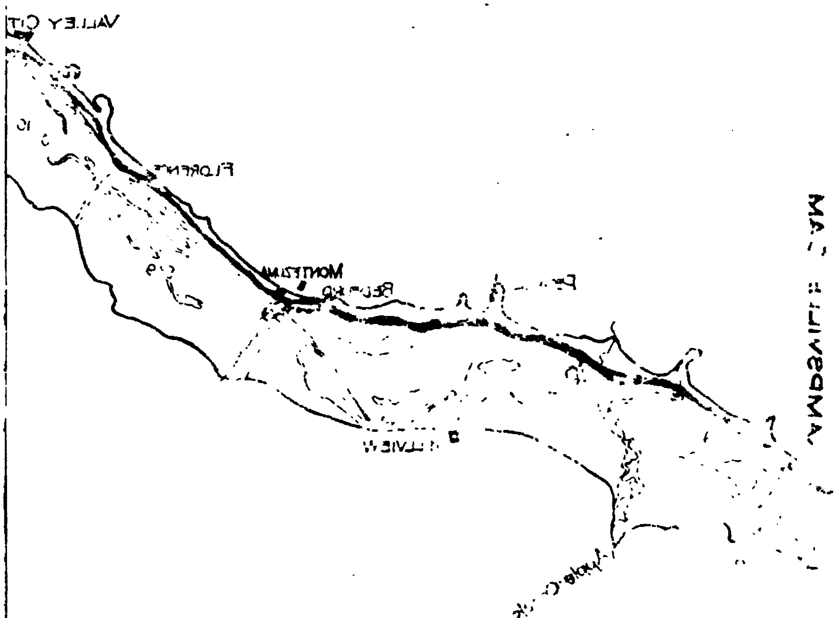

VALLEY CIT
MONTEZUMA

Fig. 7 shows the head at each dam on the first day of each month for the years 1910 and 1913, inclusive, and would serve to give a general idea of the heights prevailing in late years and throughout the different

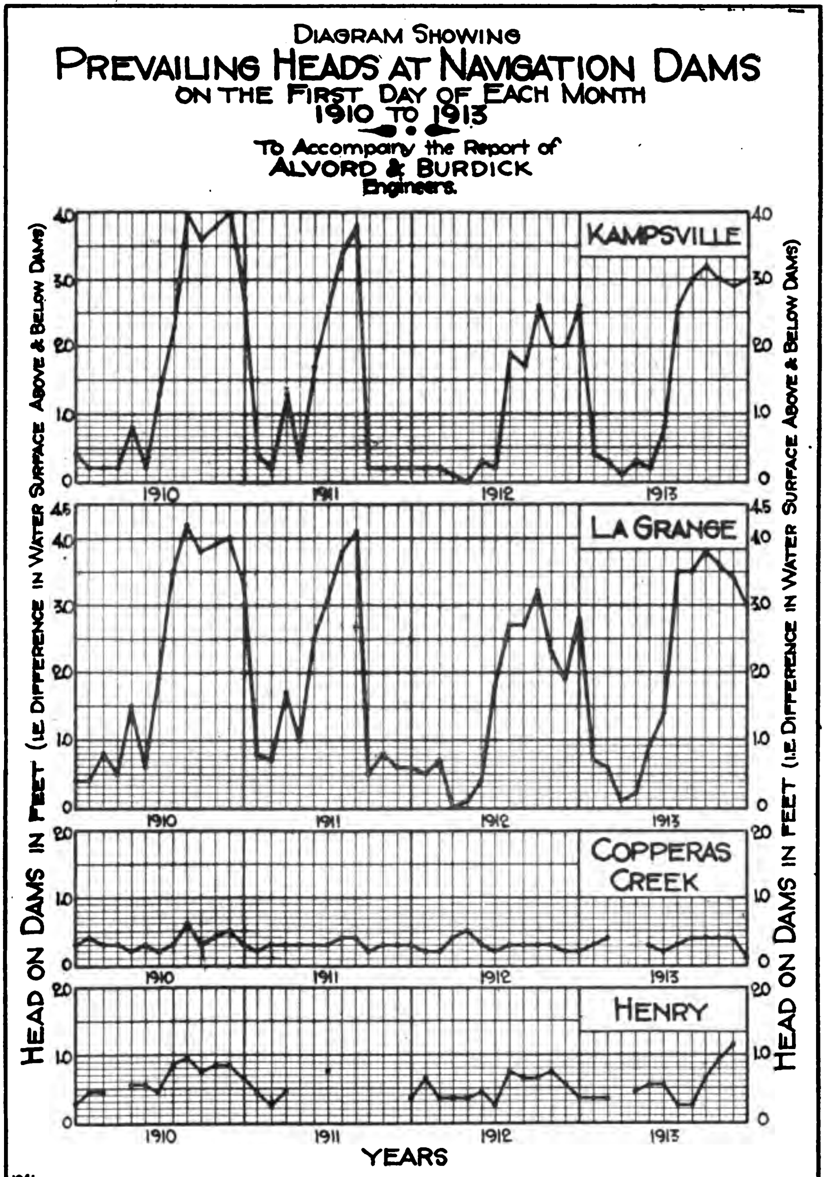


FIGURE 7.

months of the year. It will be observed that in the high water season of the year generally, the dams have practically no effect upon the water levels of the stream. During the low water season, the Kampsville and

La Grange dams increase the water level immediately above same by the amount of 2 to 4 feet. At Copperas Creek and at Henry, the low water effect is less than 1 foot.

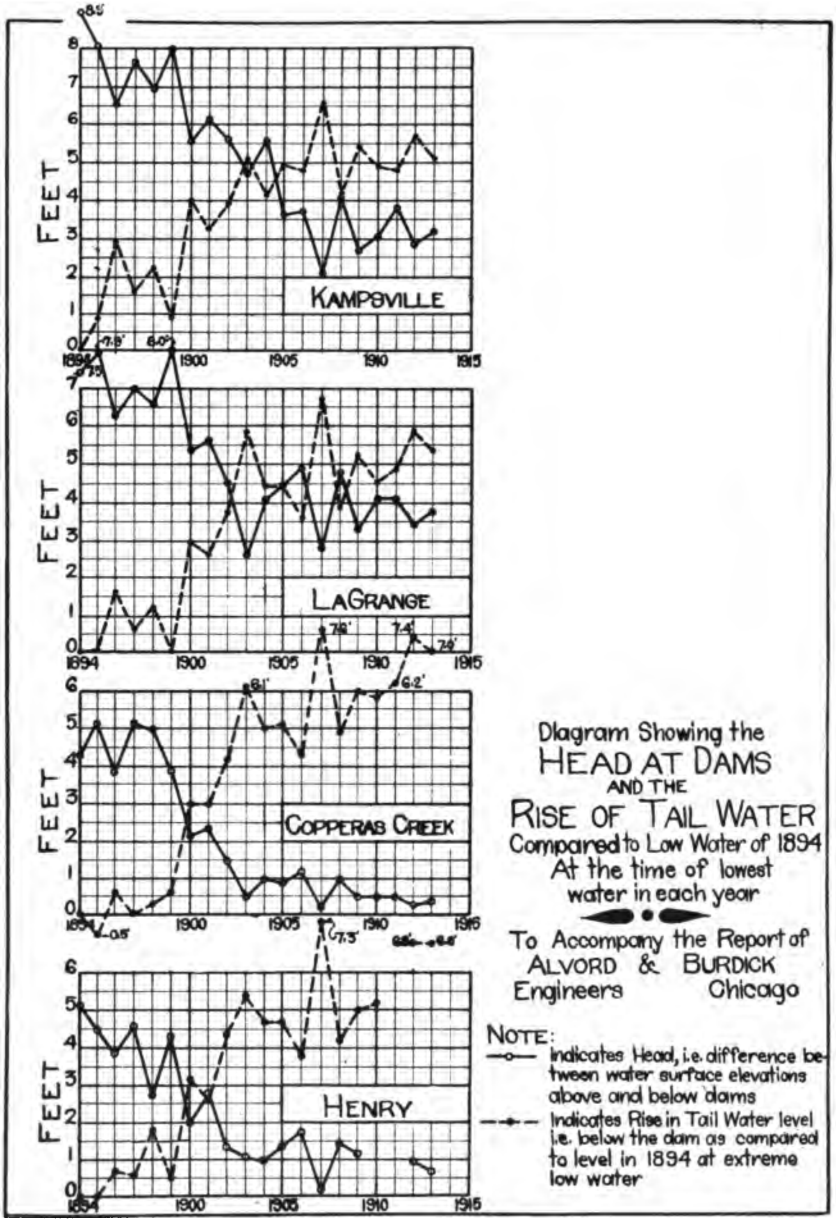


FIGURE 8.

Fig. 8 shows the heads created at the several dams at low water in each year since 1894, and the elevation of the water surface at such times immediately below the dams.

The effect upon water levels produced by these dams will grow progressively less should the flow of the Drainage Canal be further increased in the future.

REMOVAL OF DAMS.

Prior to the construction of the dams, consideration had been given to the project of improving the navigation of the river by the addition of water from Lake Michigan under open channel conditions. This scheme had been a competitor of the slack water navigation project as adopted and carried out. Since the construction of the dams, numerous projects have been studied looking toward the connection of the Mississippi River and Lake Michigan by an improved waterway. Several engineering boards have given careful study to the matter for projects of various depths of draft under various assumptions, as to the amount of water that would be available from Lake Michigan. The projects most favored for a deep waterway, 14 feet or more, have contemplated the removal of all four of the existing dams in the lower river. (See appendix for recommendation of the Rivers and Lakes Commission regarding removal of dams.)

SURVEY OF 1902-1904.

Under date of December 18, 1905, the Secretary of War transmitted to Congress the result of a study by a special board of engineers, relating to a navigable waterway 14 feet deep from the terminus of the Chicago Drainage Canal to the mouth of the Illinois River, and thence by way of the Mississippi River to St. Louis. This report was based upon an investigation, survey and study covering a period from September 18, 1902, to December 12, 1905. The investigation included a topographical survey of the river valley presented upon maps to a scale of 1 inch to 600 feet; contours of ground surface are shown at 1 foot intervals, and sufficient soundings of the rivers and principal lakes are shown in figures to form a fairly accurate conception of the under-water topography. Without these maps much of the study in the present report would have been impossible. The investigation further includes the tabulation of all available past gage height records.

It is fortunate that the flood of 1904 occurred during this investigation. Although not greatest in height, this flood perhaps produced as high a flow rate as any previous flood on record. Numerous measurements were made at various places throughout the length of the river, and furnish an invaluable basis for estimates of the water conditions likely to result from the great changes in the flood cross-section occasioned by the more recent construction of levee districts, and the further construction thereof in the future.

The original survey maps above referred to are presented upon large sheets, fifty-seven in number. For convenience in reference, lithograph maps were prepared upon a smaller scale, 1½ inches to one mile, presented on thirteen sheets. The contour interval is 5 feet upon these maps.

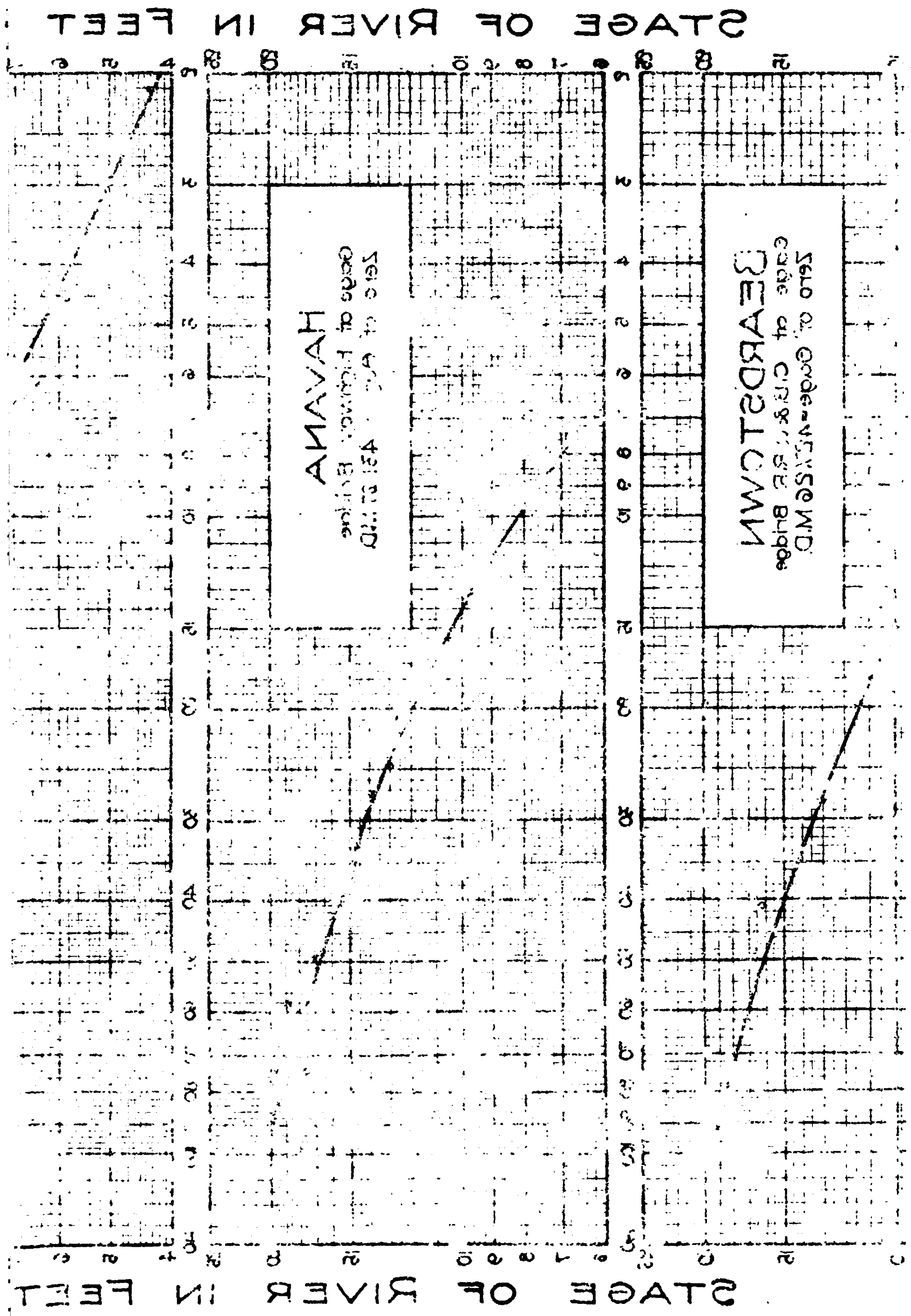
RATING CURVES.

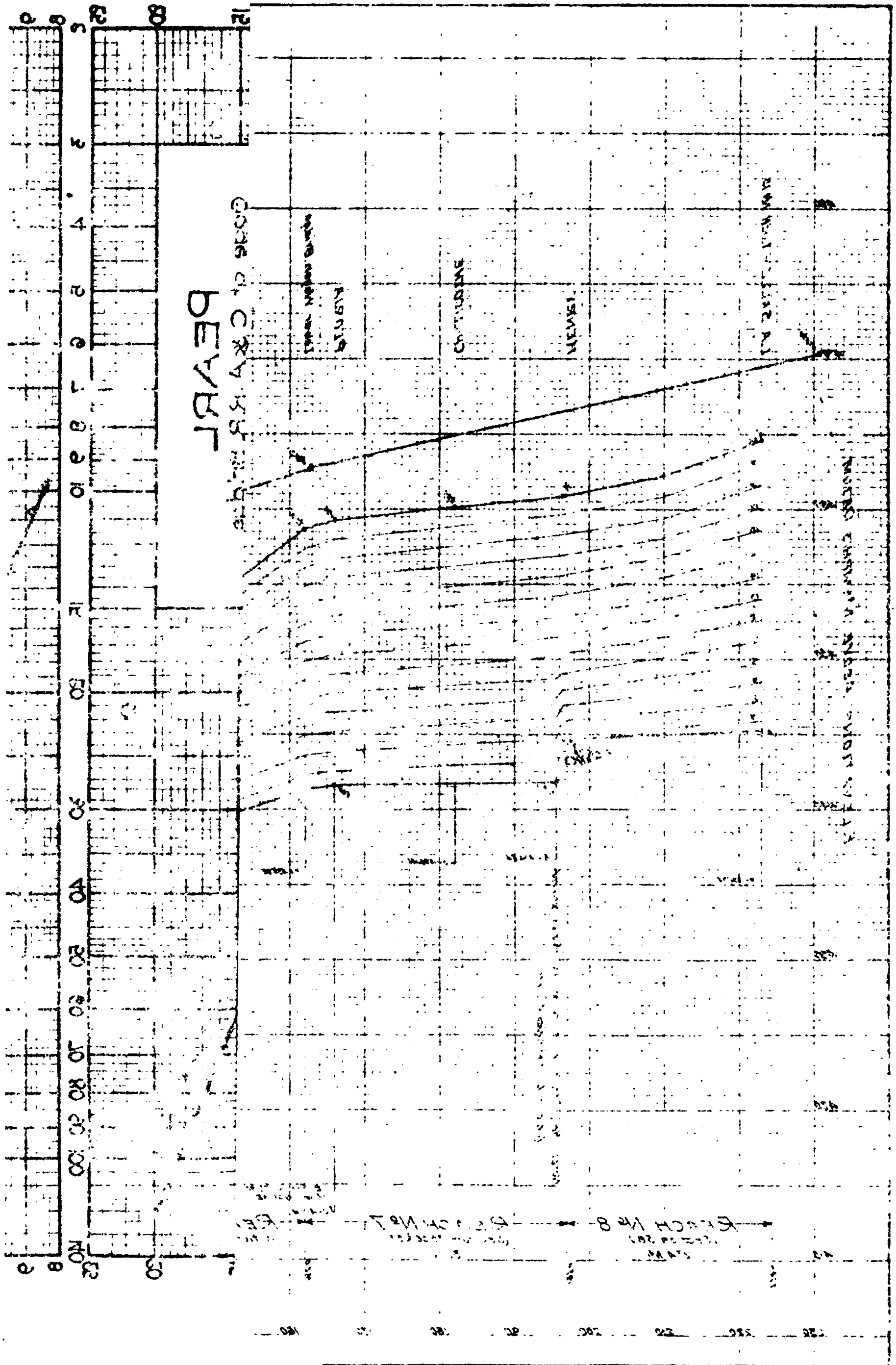
For many purposes in this report it is of use to know, at least approximately, the rate of flow that has prevailed in the river in times past at various places and under various gage heights. Accurate flow measurements of a large river are difficult to make and are expensive. It has been observed, however, that at most locations upon our streams, the gage height bears a more or less fixed relation to the rate of flow. This relation has been very extensively utilized in flow estimates of the rivers of this country, and has the great advantage, where conditions of flow prism remain practically constant over a considerable reach of the river, that information as to the relation of gage height and flow when once secured, can be applied to the gage records of the stream, and thus the flows can be estimated over a long period of time.

At any observation station the relation of gage height to flow is approximate only, for the rate of flow will change with a change in the water surface slope, and this slope may vary considerably, especially in flood, by reason of the inequalities in water supply from the various tributaries of the main stream.

Furthermore, the results from any gaging station will be accurate in proportion to the lack of influence from downstream interferences arising from the causes other than the rate of flow on the stream measured. For instance, the gage at Grafton at the mouth of the Illinois River, might possibly be a good index of flow for the Mississippi at that place, but is influenced to only a minor extent by the water from the Illinois River. Likewise, the gages in the lower Illinois River are very largely influenced by the gage height and flow on the Mississippi, but the effect of the Mississippi decreases, and the effect of the flow on the Illinois increases as the Illinois River is ascended. It is probable that not until Peoria is reached the height of the Mississippi has a negligible effect upon the flow inference from gage height.

It is customary to utilize the relation between gage height and flow at any particular place, by platting a diagram of gage height and flow, platting thereon each individual observation, and drawing a curve of average relation most nearly in accordance with the facts as disclosed. For accurate results it is important to have a large number of observations well distributed along the curve. They will not always be concordant for the reasons above stated, but where a sufficient number of observations have been made, the curve drawn should represent with fair accuracy the average relation between gage height and flow. It is, therefore, a good index of aggregate flow, especially over a long period of unchanged river conditions, but is much less accurate when applied to individual flows. It furnishes the best means available of approximating the flows at various times and places upon the Illinois River. We have examined all the data of flow measurements of the river that we could find. We have summarized this information in the form of rating curves at several salient points as shown upon Fig. 9, namely, at La Salle, Peoria, Havana, Beardstown and Pearl. At none of these places, except it be Peoria or Havana, are the flow measurements sufficiently extensive to draw deductions except within certain limitations. The information at these places, however, is useful so far as it goes, and


STAGE OF RIVER IN FEET
HAVANA
Gage at Havana Bridge
BEARDSTOWN
Gage at C.B.&Q. R.R. Bridge
STAGE OF RIVER IN FEET



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is therefore deemed worthy of presentation. In the use of these data, the limitations of the downstream gages, particularly in reference to interference from downstream, should be kept in mind.

RATING CURVE AT PEORIA.

The mouth of Lake Peoria furnishes, perhaps, as good a gaging station as can be found upon the river, the water as it were, falling over the lip of a weir at Peoria Lake, with a more rapid descent towards Pekin and below. Near this place a large number of flow measurements have been made, including measurements by the U. S. Engineers in 1904, in connection with the waterway report; by the U. S. Geological Survey in 1903, 1904, 1905, and 1906, and also by Jacob A. Harman, C. E., in 1899 and 1900. Fig. 9 shows the measurements by these separate agencies, each by appropriate symbols.

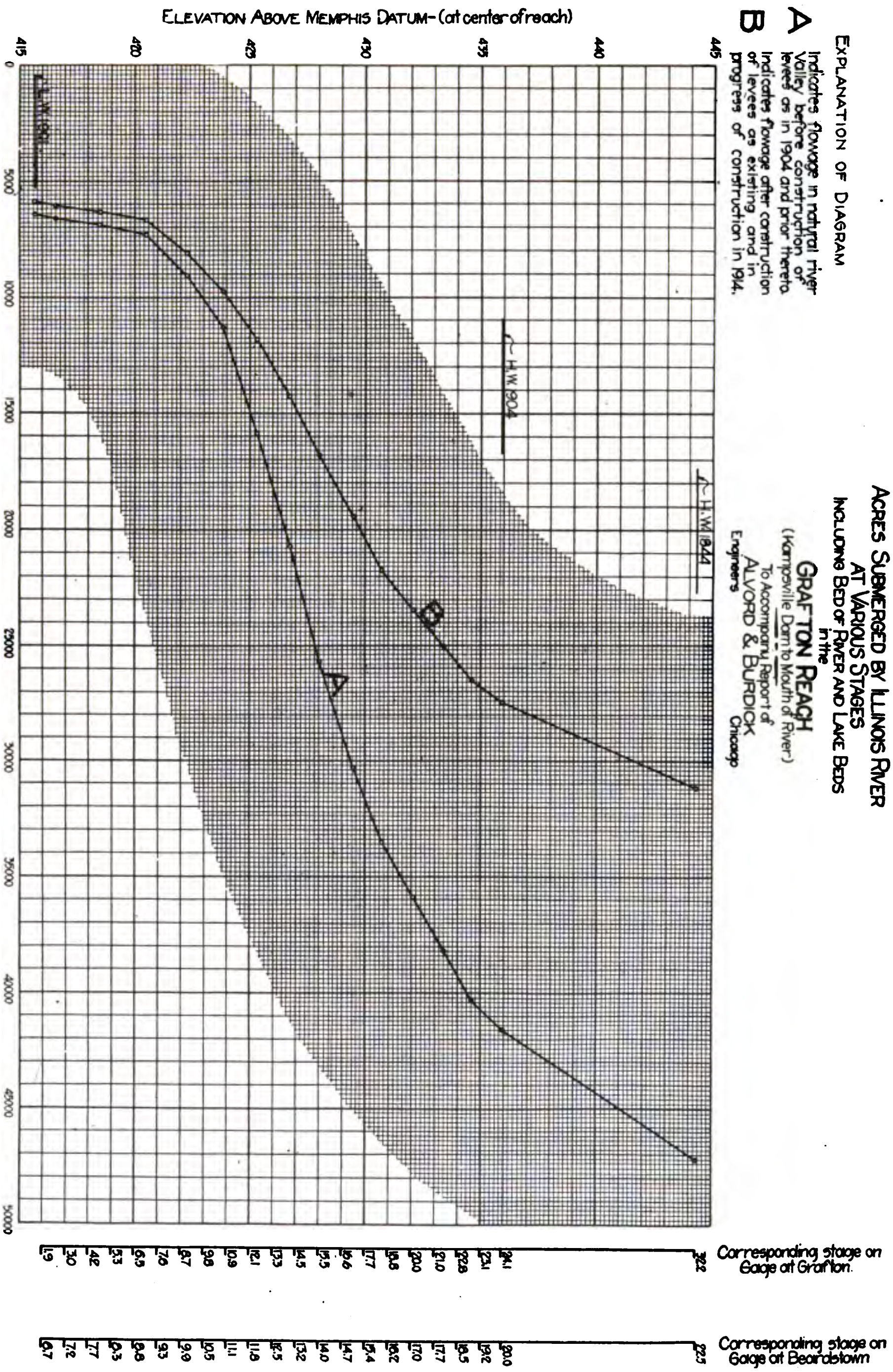
The measurements by Mr. Harman are particularly valuable in that they cover stages of water 3 feet lower than any of the more recent measurements. Fig. 9 shows two curves at Peoria. The long straight line represents the conclusions of Mr. Harman. His measurements were made at the lower wagon bridge. The measurements of the U. S. Geological Survey and those of the U. S. Engineers were made at the P. & P. U. Ry. Bridge, about one and one-half miles further downstream. As imultaneous gage readings are available at the two bridges, it is ossible to transfer the measurements at the P. & P. U. Bridge to read as er heights at the wagon bridge, and as a long gage record is here ilable, we have thus transferred the P. & P. U. Bridge measurements in the rating curve presented. The full curved line represents the conclusion of the U. S. Geological Survey and its dotted extension is our conclusion as to the flow at the higher gage readings.

The flow hydrograph at Peoria shown at the bottom of Fig. 4 is based upon the Harman curve up to gage 7½, and for higher stages refers to the U. S. Geological Survey curve, as extended.
clusion of the U. S. Geological Survey and its dotted extension is our conclusion as to the flow at the higher gage readings.

SUBMERGED LANDS.

For numerous purposes in this report it is desirable to know approximately the amount of land submerged under various stages of the river. It is of significance in the consideration of several matters including the reduced river valley storage occasioned by the leveeing of farm lands and the consequent tendency to increase flood flow rates. It is useful in determining the extent to which reclamation will continue at various localities in the river valley, and it has a bearing upon the fisheries, for the flood waters and the flooded lands are important breeding and feeding grounds for fish.

In order that reliable figures relative to this matter might be secured, the large scale topographical maps of the 1904 Engineer Board were planimetered at the low water plane of 1901 and at other salient water planes in general 5 feet apart, up to or slightly above the high water plane of 1844, the highest flood on record.



Elevation Above Memphis Datum - (at center of reach)
Acres Submerged
Explanation of Diagram
A Indicates flowage in natural river valley before construction of levees as in 1904 and prior thereto.
B Indicates flowage after construction of levees as existing, and in progress of construction in 1914.
Acres Submerged by Illinois River at Various Stages Including Bed of River and Lake Beds in the
Grafton Reach
(Kampsville Dam to Mouth of River)
To Accompany Report of
Alvord & Burdick
Engineers Chicago
H.W. 1904
H.W. 1844
Corresponding stage on Gage at Grafton.
Corresponding stage on Gage at Beardstown

FIGURE 11.

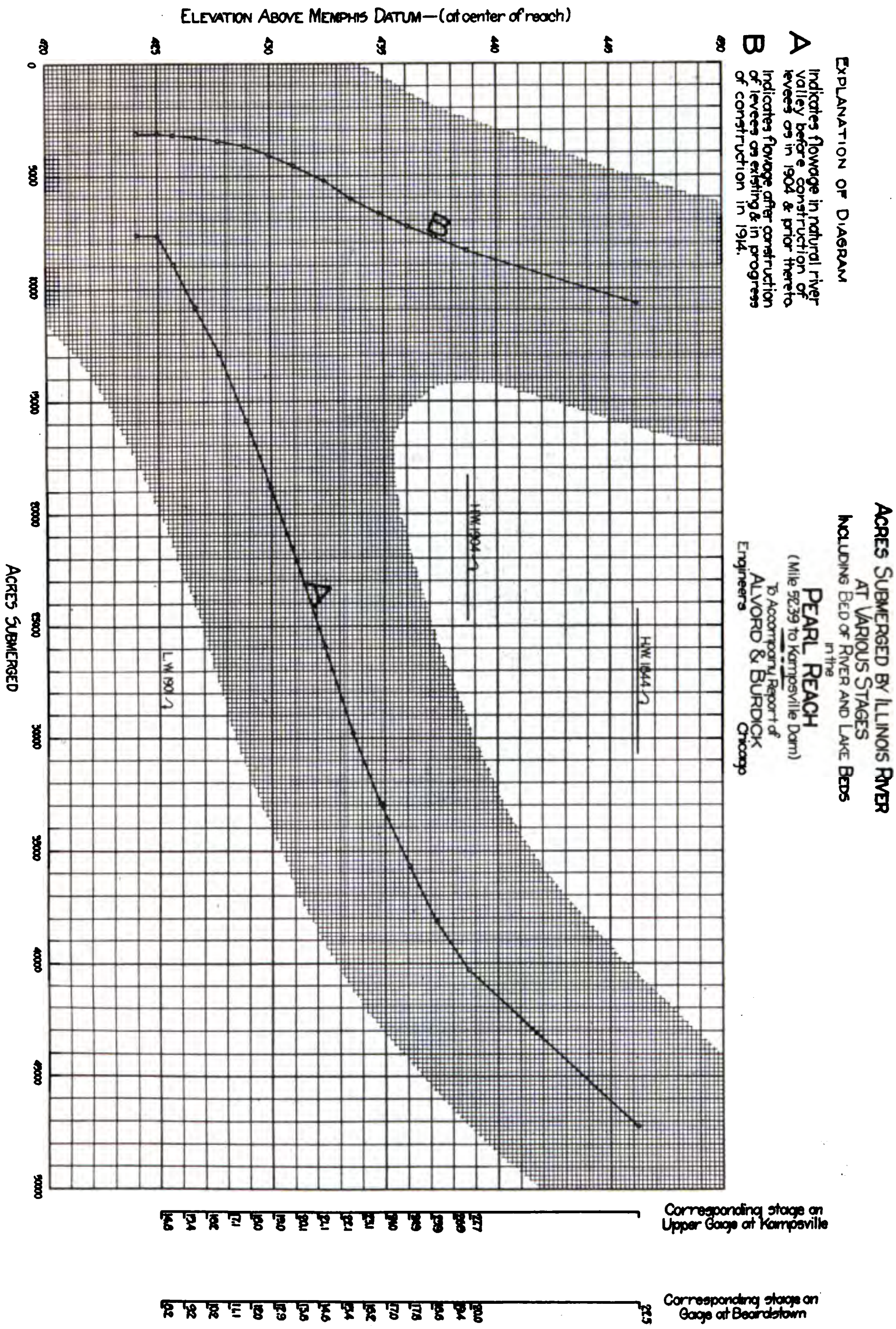
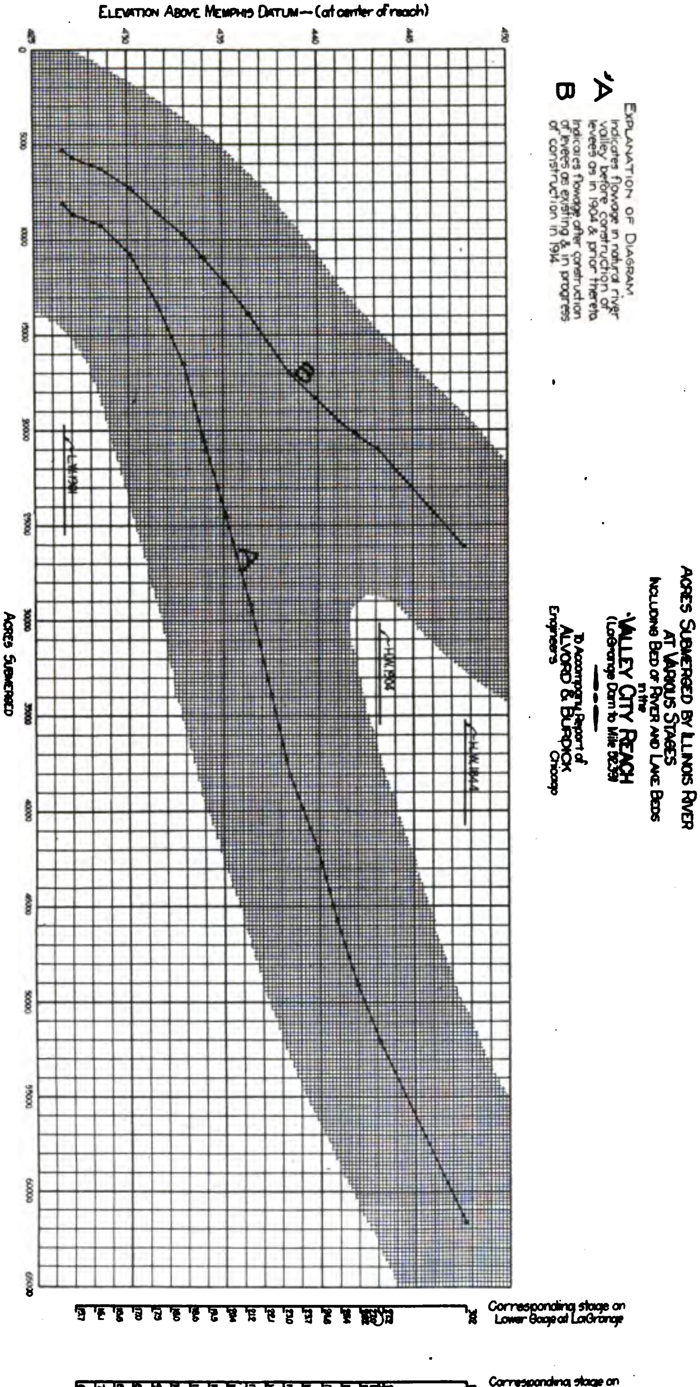

Acres Submerged by Illinois River at Various Stages
Including Bed of River and Lake Beds
in the
Pearl Reach
(Mile 92.39 to Kampsville Dam)
To Accompany Report of
Alvord & Burdick
Engineers Chicago
Explanation of Diagram
A Indicates flowage in natural river valley before construction of levees as in 1904 & prior thereto.
B Indicates flowage after construction of levees as existing & in progress of construction in 1914.
Elevation Above Memphis Datum—(at center of reach)
Acres Submerged
H.W. 1904
H.W. 1844
L.W. 1901
Corresponding stage on Upper Gage at Kampsville
Corresponding stage on Gage at Beardstown

FIGURE 12.



ELEVATION ABOVE MEMPHIS DATUM—(at center of reach)
ACRES SUBMERGED
EXPLANATION OF DIAGRAM
A Indicates flowage in natural river valley before construction of levees as in 1904 & prior thereto.
B Indicates flowage after construction of levees as existing & in progress of construction in 1914.
ACRES SUBMERGED BY ILLINOIS RIVER AT VARIOUS STAGES INCLUDING BEDS OF RIVER AND LAKE BEDS in the VALLEY CITY REACH
To Accompany Report of ALVORD & BURDICK Engineers Chicago
Corresponding stage on Lower Gage at LaGrange
Corresponding stage on Gage at Beardstown

FIGURE 13.

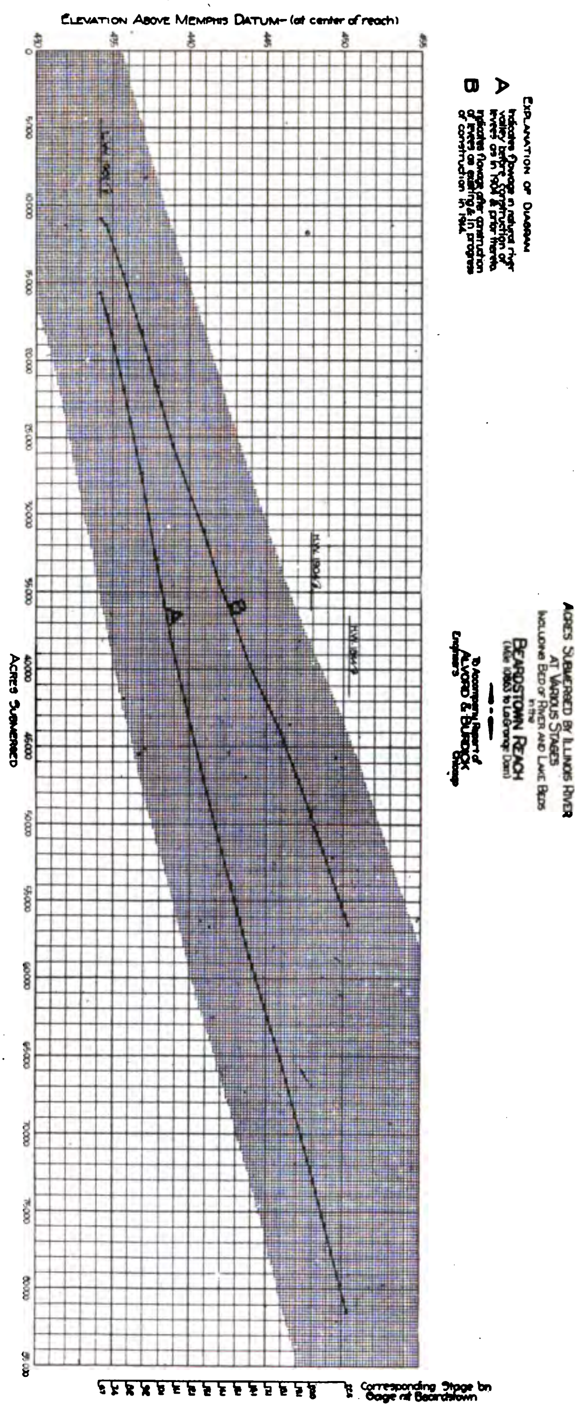

Elevation Above Memphis Datum—(at center of reach)
Acres Submerged
Explanation of Diagram
A
B
Acres Submerged by Illinois River
at Various Stages
Including Bed of River and Lake Beds
in the
Beardstown Reach
Alvord & Burdick
Corresponding Stage on Gage at Beardstown

FIGURE 14.

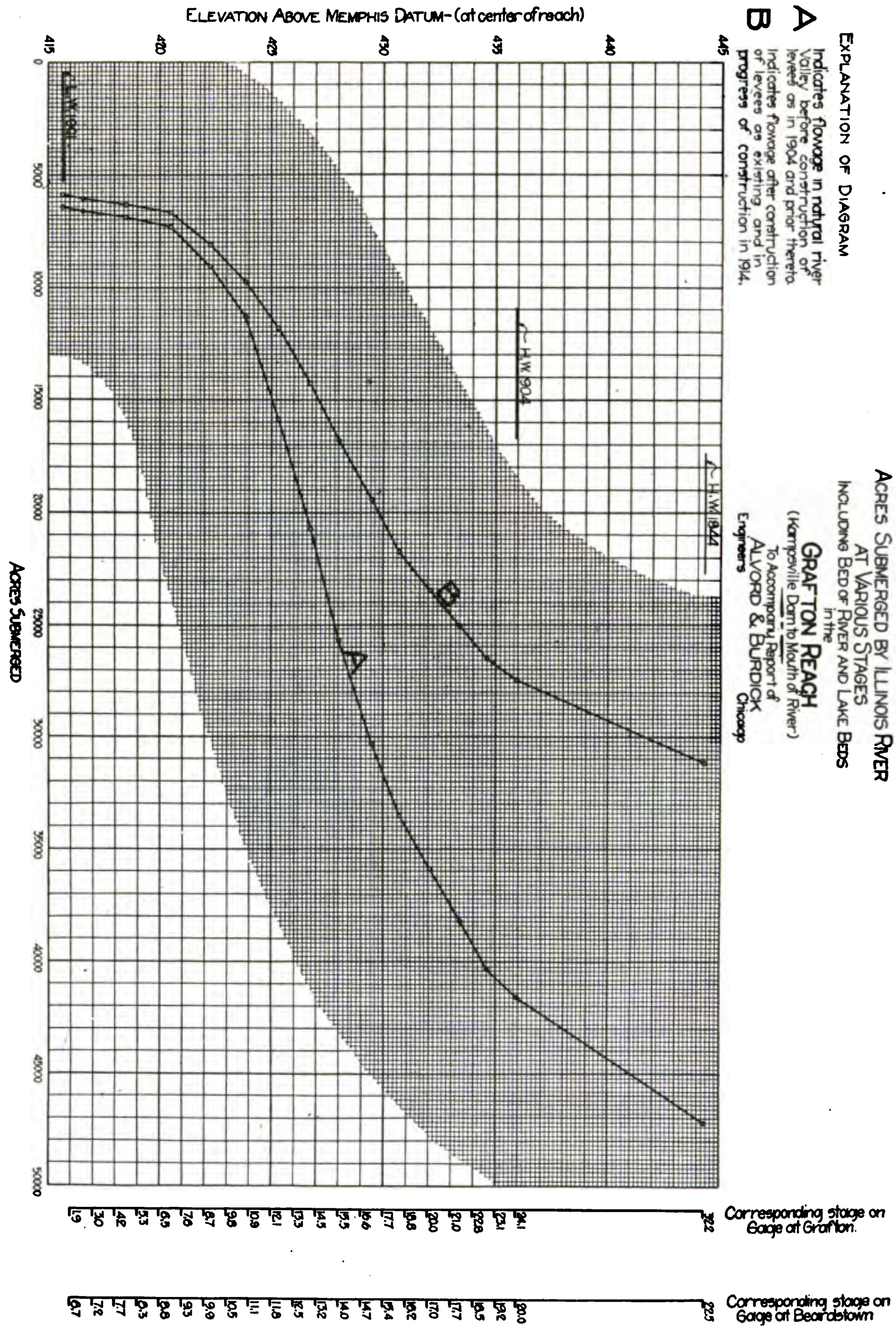

Acres Submerged by Illinois River
at Various Stages
Including Bed of River and Lake Beds
in the
Grafton Reach
(Kampsville Dam to Mouth of River)
To Accompany Report of
Alvord & Burdick
Engineers Chicago
Explanation of Diagram
A Indicates flowage in natural river valley before construction of levees as in 1904 and prior thereto.
B Indicates flowage after construction of levees as existing and in progress of construction in 1914.
Elevation Above Memphis Datum-(at center of reach)
Acres Submerged
H.W. 1904
H.W. 1844
L.W. 1901
Corresponding stage on Gage at Grafton.
Corresponding stage on Gage at Beardstown

FIGURE 11.

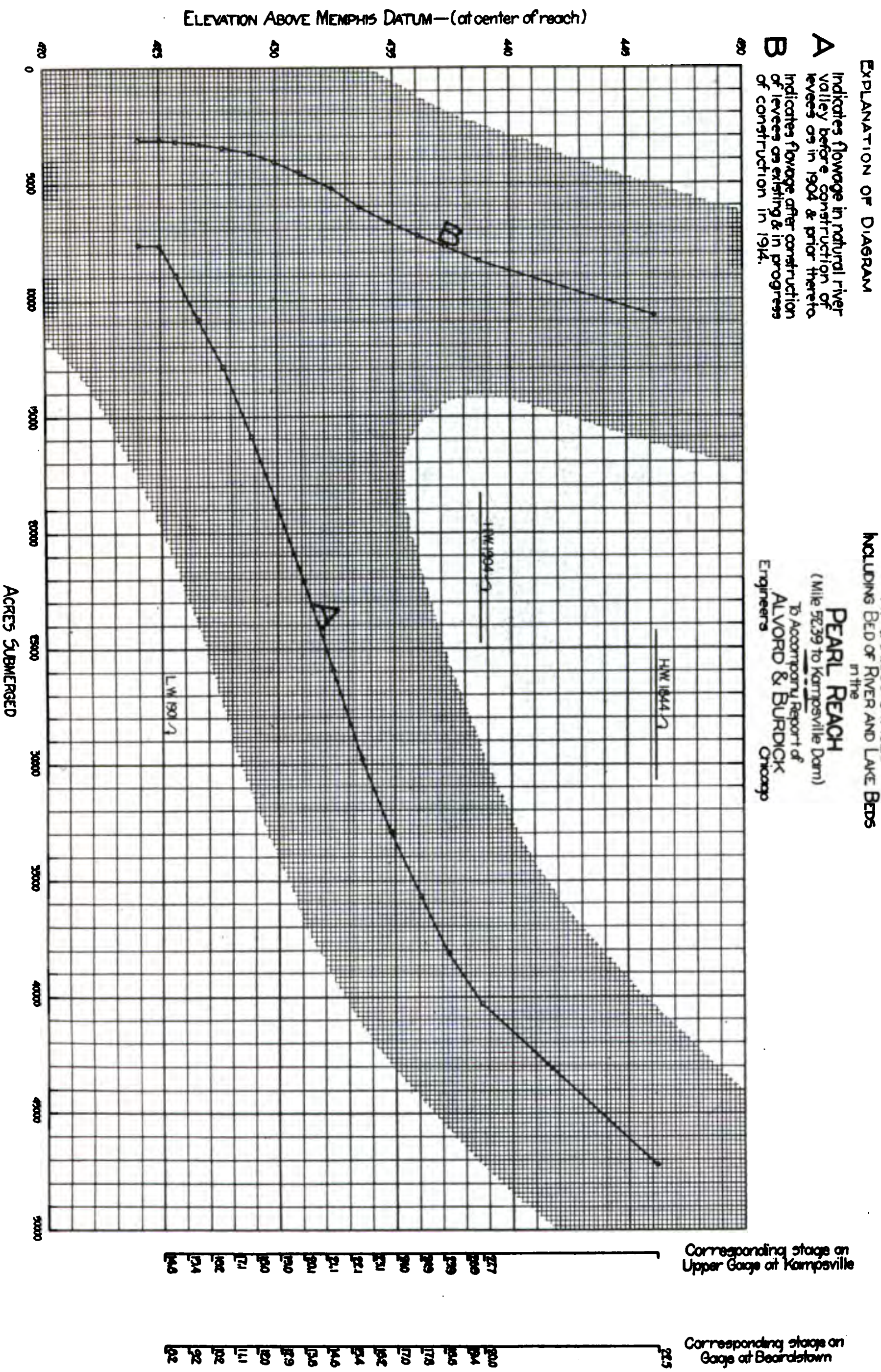

Elevation Above Memphis Datum—(at center of reach)
Explanation of Diagram
A Indicates flowage in natural river valley before construction of levees as in 1904 & prior thereto
B Indicates flowage after construction of levees as existing & in progress of construction in 1914.
Acres Submerged by Illinois River
at Various Stages
Including Bed of River and Lake Beds
in the
Pearl Reach
(Mile 92.39 to Kampsville Dam)
To Accompany Report of
Alvord & Burdick
Engineers Chicago
H.W. 1904
H.W. 1844
L.W. 1901
A
B
Acres Submerged
Corresponding stage on Upper Gage at Kampsville
Corresponding stage on Gage at Beardstown

FIGURE 12.

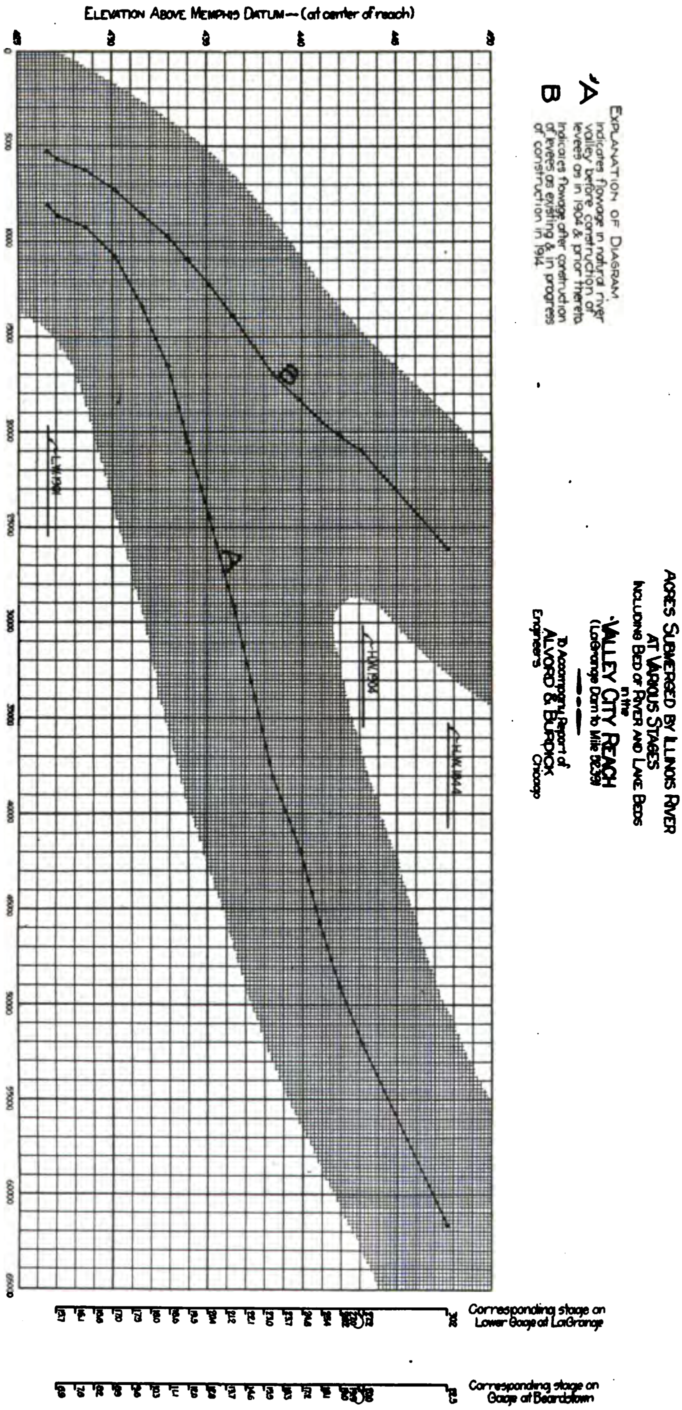

Elevation Above Memphis Datum—(at center of reach)
Acres Submerged
Explanation of Diagram.
'A Indicates flowage in natural river valley before construction of levees as in 1904 & prior thereto.
B Indicates flowage after construction of levees as existing & in progress of construction in 1914
Acres Submerged by Illinois River at Various Stages Including Bed of River and Lake Beds in the Valley City Reach
To Accompany Report of Alvord & Burdick Engineers Chicago
Corresponding stage on Lower Gage at LaGrange
Corresponding stage on Gage at Beardstown

FIGURE 13.

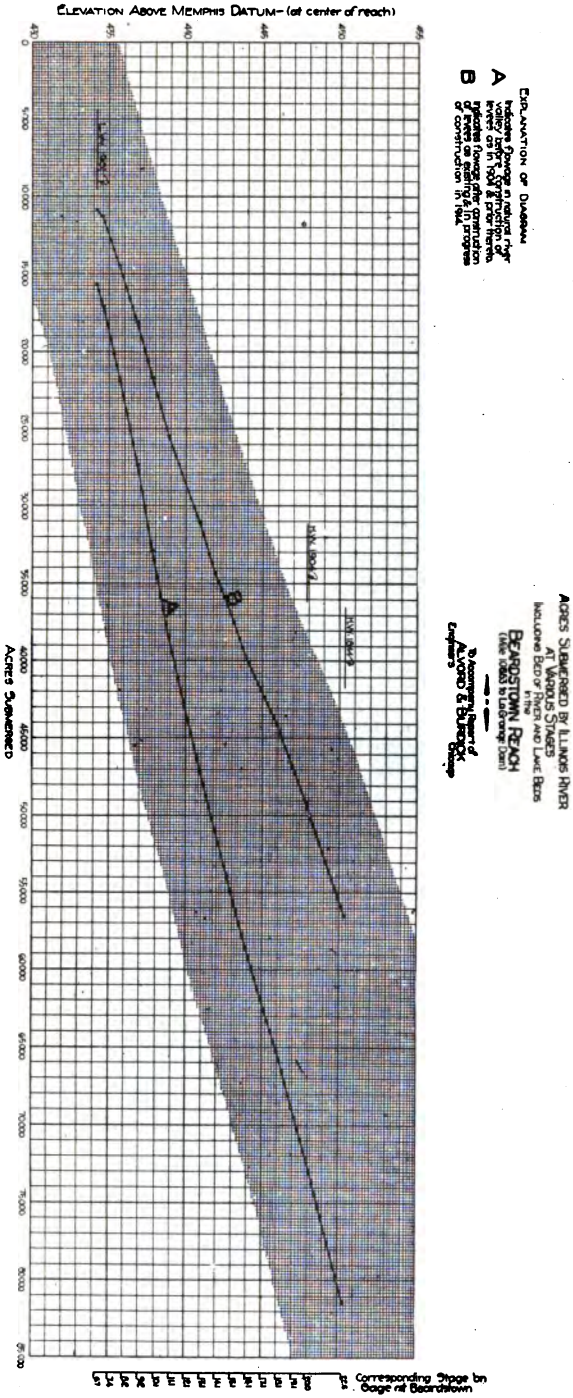

Elevation Above Memphis Datum—(at center of reach)
Acres Submerged
Explanation of Diagram
A Indicates flowage in natural river valley before construction of levees as in 1904 & prior thereto.
B Indicates flowage after construction of levees as existing & in progress of construction in 1914.
Acres Submerged by Illinois River at Various Stages
Including Bed of River and Lake Beds in the
Beardstown Reach
To Accompany Report of Alvord & Burdick Engineers Chicago
Corresponding Stage on Gage at Beardstown

FIGURE 14.

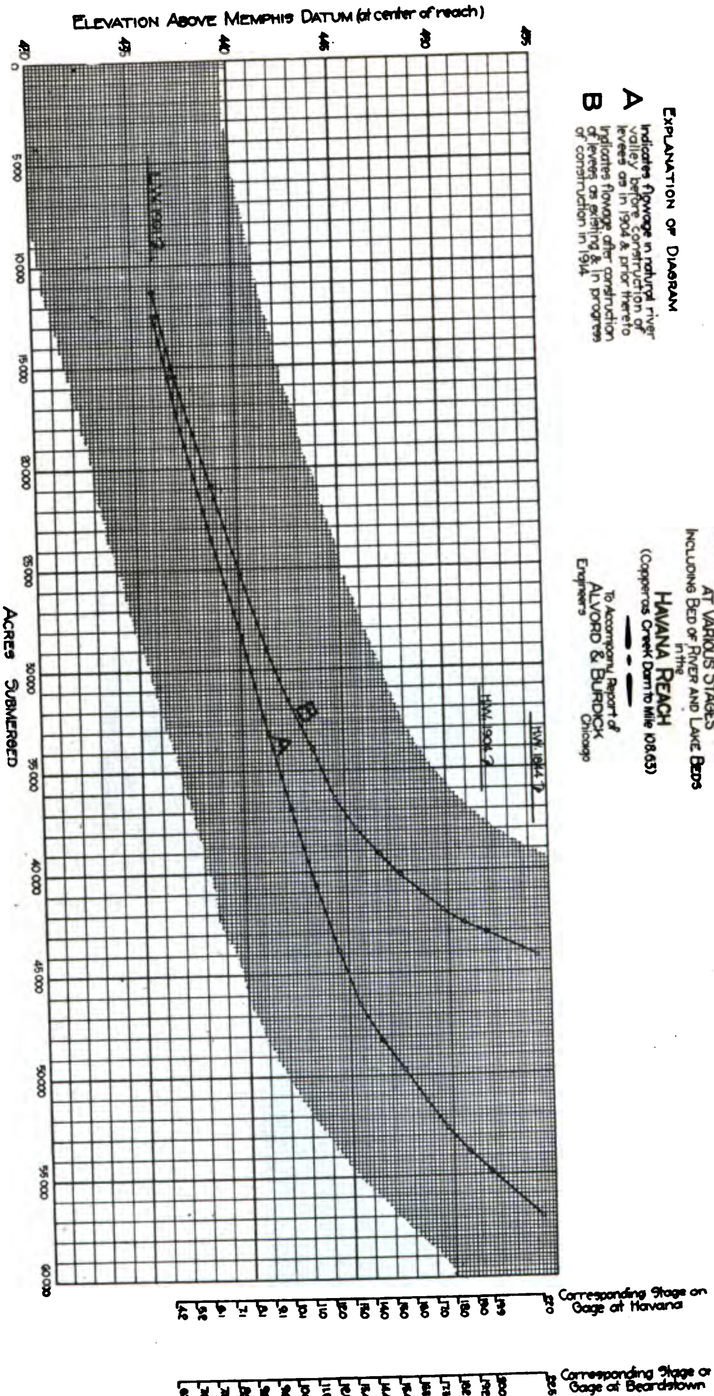
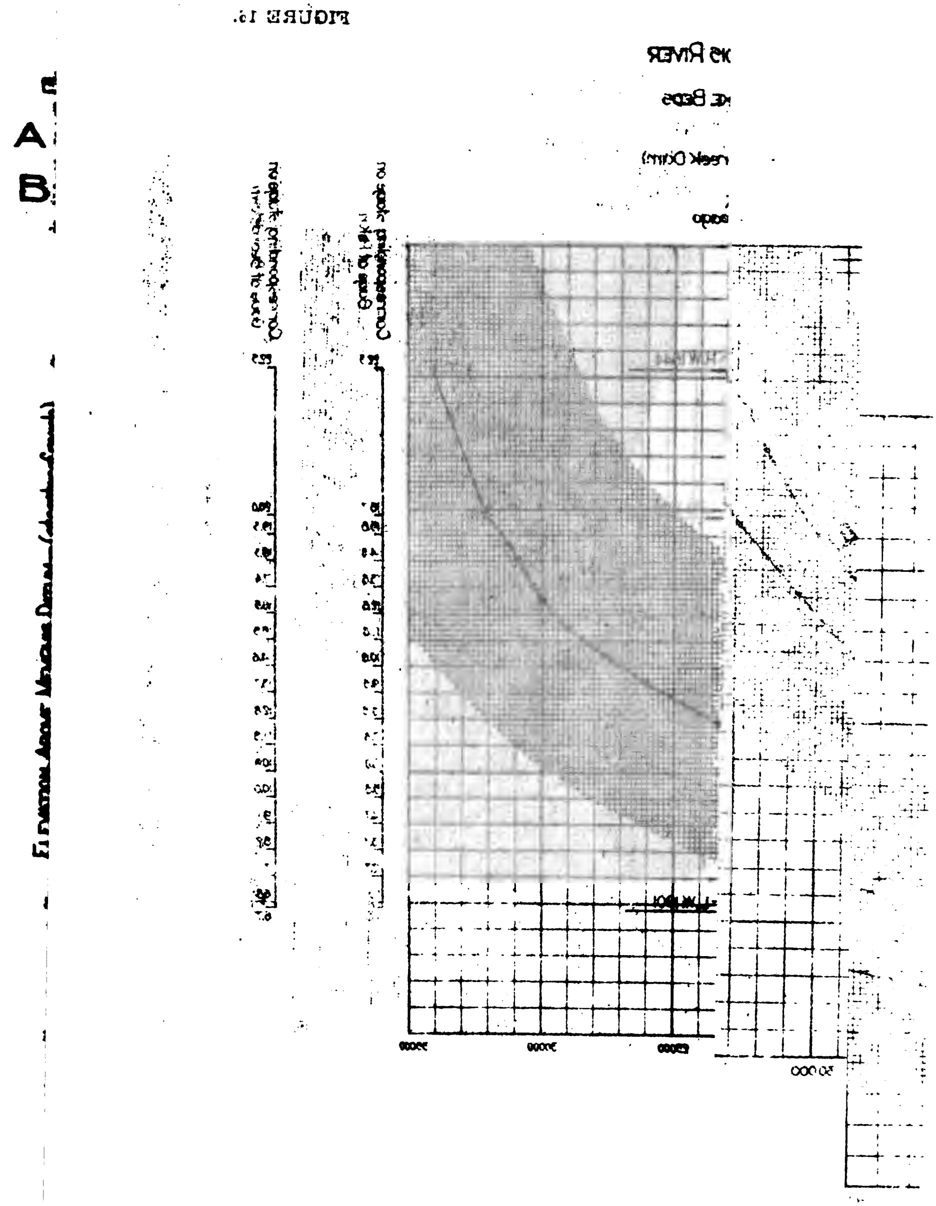

Elevation Above Memphis Datum (at center of reach)
Acres Submerged
Explanation of Diagram
A Indicates flowage in natural river valley before construction of levees as in 1904 & prior thereto
B Indicates flowage after construction of levees as existing & in progress of construction in 1914
Acres Submerged by Illinois River at Various Stages
Including Bed of River and Lake Beds
in the
Havana Reach
(Copperas Creek Dam to Mile 108.63)
To Accompany Report of
Alvord & Burdick
Engineers Chicago
Corresponding Stage on Gage at Havana
Corresponding Stage on Gage at Beardstown

FIGURE 15.



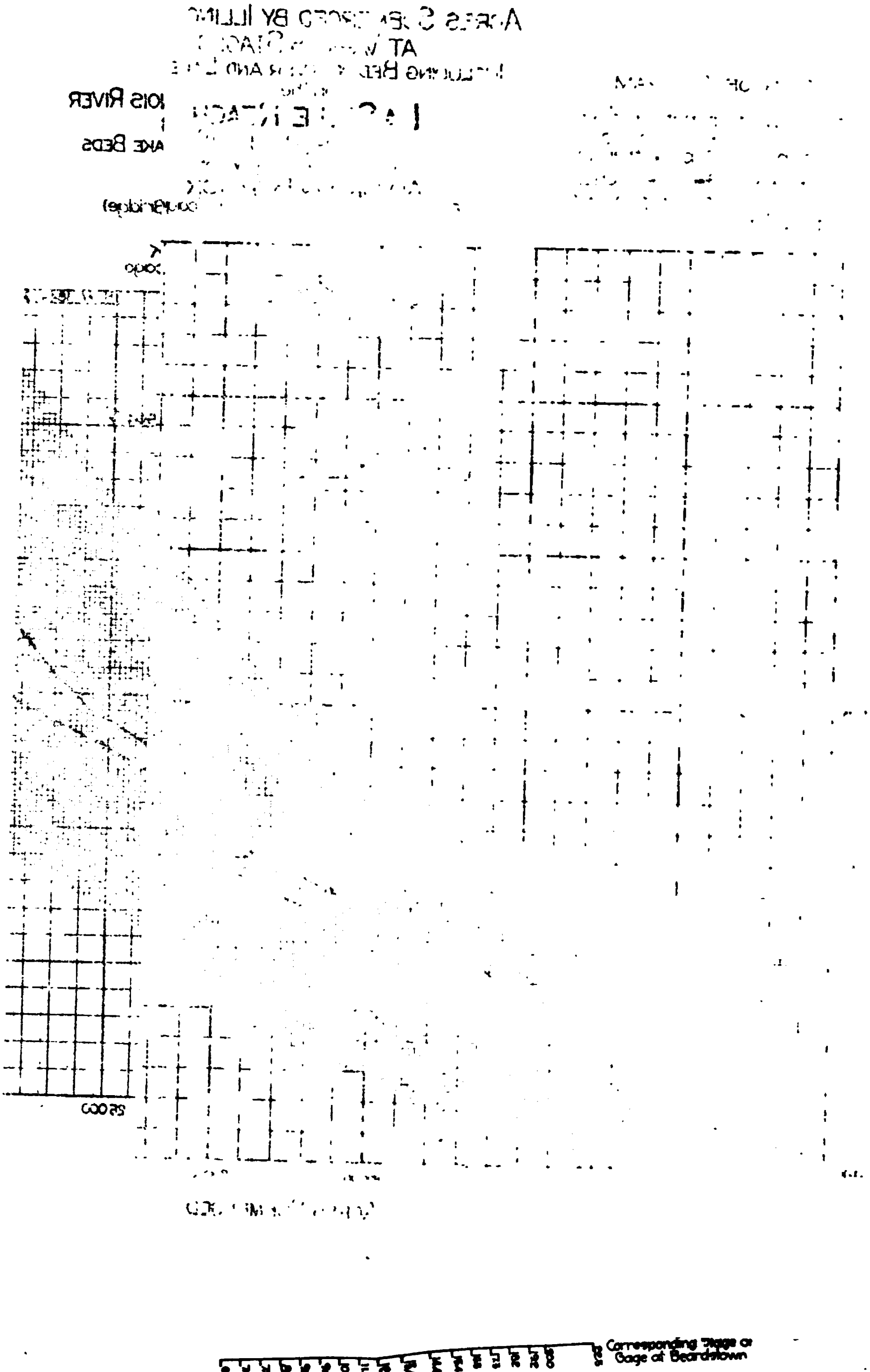


FIGURE 15.

ACRES SUBMERGED BY ILLINOIS RIVER

LA SALLE TO MOUTH

UNDER

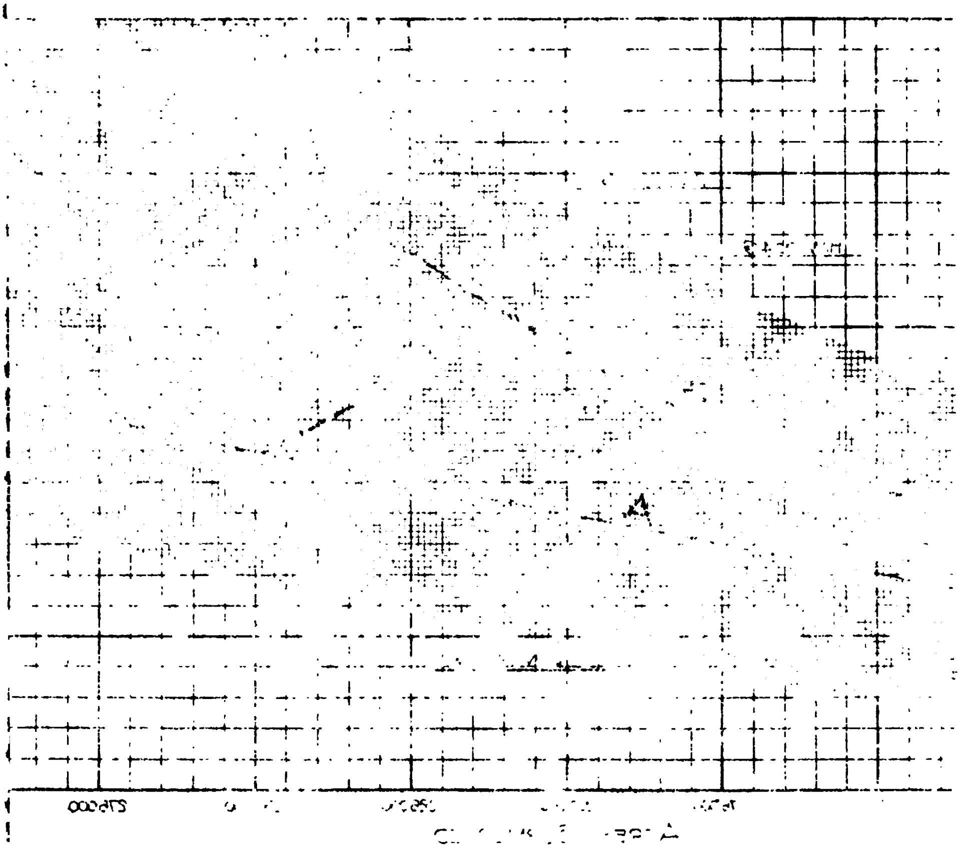
NORMAL VARIATIONS IN RIVER STAGE

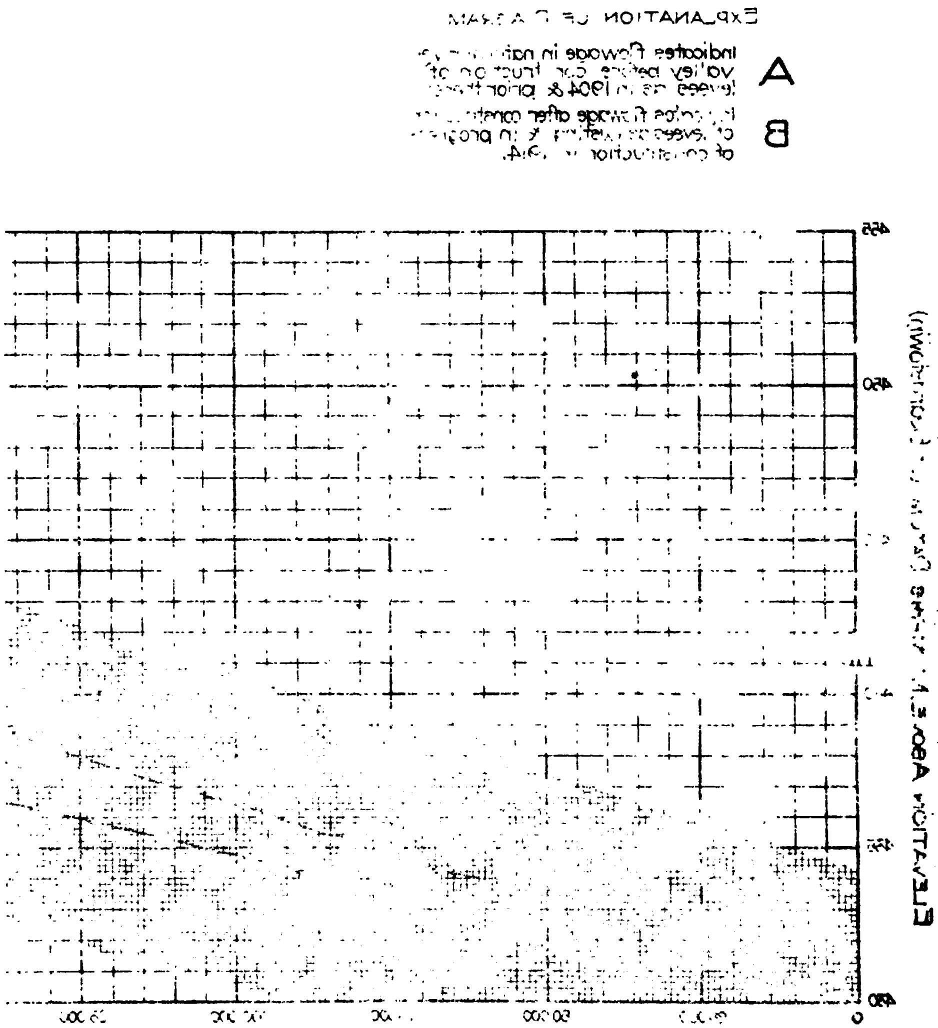
INCLUDING BED OF RIVER AND LAKE BEDS

To Accompany Report of

ALVORD & BURDICK

Engineers Chicago





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For convenience the minutes of latitude were used to divide the river into convenient sections below Peoria. The sections were nearly all two minutes in width measured north and south, extending across the river valley, and were thus about 2½ miles in dimension parallel to the general trend of the river valley. Curves of water area were drawn for each section in reference to the height of water surface above Memphis datum plane.

NORMAL FLOW PROFILES.

For practical purposes, it was necessary to combine these sections into groups more or less distinctive of the several reaches of the whole stream. As the slope of the water plane becomes of importance in combining several of the small sections, and further in view of the fact that it is a series of numerous sloping water planes that govern the water acreage at various gage heights, it was thought that the information as to water acreage could be best expressed in terms of the gage height at some salient place such as Beardstown. For this purpose Fig. 10 was prepared, which is intended to represent the normal gage height relation throughout the river from La Salle to Grafton, for river stages between the low water of 1901 and the high water of 1904. This was done by determining as nearly as possible, the average correlation of the various gages through platting a large number of observations of each gage against the simultaneous reading at Beardstown.

The series of profiles thus represented, would not be expected to closely correspond to the profile in any particular flood, for the flood will vary in height upon the different reaches of the river in accordance with the varying contributions from the different tributaries of the main stream. Upon the average, however, the curves represent the composite of the conditions constantly recurring, and varying for local reasons from day to day above and below the water profiles represented. The slopes in the river valley, particularly on account of the dams, vary with stage, and for a given gage height at the foot of a certain reach, the acreage overflowed will vary with the slope of the water surface. It was, therefore, deemed important to determine a normal slope for each gage height in order that a normal or average acreage could be determined.

CURVES OF FLOWAGE.

Diagrams of water acreage at various river stages are presented in Figs. 11 to 19, inclusive. Two curves of acreage are shown, namely—first, (curve "A") the virgin river valley as it existed before levee operations were begun, or prior to 1904, and second, (curve "B") the water acreages at present with the levee districts as now completed or in process of construction.

The acreages for the entire river from La Salle to the mouth are shown upon Fig. 19. At the left of the diagram, the elevation of water surface is shown at Beardstown, in reference to the Memphis datum plane, and at the right of the diagram, corresponding heights upon the Beardstown gage, and also the stage usually prevailing at Grafton for certain elevations at Beardstown. The stage at Grafton resulting from

a given stage at Beardstown, will of course, vary widely, and the relation indicated is no more than an average relation. The relation will, however, be usually roughly correct, for generally, rivers in the same locality are in greater or less degree of flood at the same season.

The diagram is read thus: During the low water of 1901 the Beardstown gage read just under 6.75, corresponding to a Memphis datum elevation of 434. The total water acreage including the lakes and ponds was 77,000 as indicated by curve "A". Under present conditions, owing to construction of levee districts which has cut off numerous lakes from connection with the river at a similar gage height, the water acreage would be 68,000, (curve "B") the difference in the acreages named representing the water surface reclaimed. It should be said that not all these lakes are drained, but they are enclosed within levees which make them inaccessible from the river, and many of the lake beds are farmed. With an elevation of 12.75 on the Beardstown gage, corresponding to 440 feet Memphis datum, the area of the water surface from La Salle to Grafton would be 225,000 acres in the virgin river valley, and 152,000 acres as now partially reclaimed. Likewise, it will be noted that at an elevation corresponding to the flood of 1844, the acreage in the virgin river valley is 398,000, and as reclaimed, 249,000, assuming that the levees all extended above the 1844 flood water plane, which corresponds to elevation 22.5 on the Beardstown gauge. Fig. 11 shows similar information in reference to that part of the river valley between Grafton and Kampsville dam. The elevations at the left of the diagram refer to the elevation in the center of this reach, and at the right of the diagram, the corresponding stage is shown at Grafton, the nearest governing gage, and also the usually corresponding stage at Beardstown.

Fig. 12 shows the same information for the so-called Pearl reach, so named from the principal town thereon, and extending from the Kampsville dam to mile 52. (See mileage marked on Fig. 10.) In this reach of the river the farm land has been nearly all reclaimed. The acreage of water at the flood level of 1844 in the virgin valley was 47,200. A repetition of this flood height would produce an acreage of only 10,700, indicating that the flood water surface has been reduced nearly 80 per cent through the construction of levees. There is a similar reduction at all stages of water though not quite so great at the low stages. This reach is completely leveed and probably represents a maximum that may be used as a guide for estimating the future possibilities on the remainder of the river. An examination of the succeeding diagrams shows a less percentage of the land reclaimed in the upper parts of the river, except in the vicinity of Pekin where a little more than half of the bottom lands in the so-called Pekin reach has been reclaimed. Reclamation above Pekin has not been extensive on account of the relatively small width of the bottom lands, and probably never will be as extensive as the operations in the lower river.

Table No. 10 summarizes numerically the principal figures of acreage, and shows separately the acres in river bed, lake beds, and the land overflowed, under several stages of water. The land acreage as tabulated is the total water acreage after deducting river bed and lake beds at the plane of low water in 1901.

TABLE NO. 10—WATER ACREAGES AND LAND OVERFLOWED, ILLINOIS RIVER—LA SALLE TO GRAFTON—UNDER CONDITIONS BEFORE AND AFTER CONSTRUCTION OF LEVEE DISTRICTS AS EXISTING OR UNDER CONSTRUCTION IN 1914.

Name of reach.	Location of reach—		Length of reach in miles.	Acres in river surface, L. W. 1901.	In virgin river valley before leveed.							In present reclaimed river valley.						
					Acres in lakes, L. W. 1901.	Acres under water as in flood heights of—						Acres in lakes, L. W. 1901.	Acres under water as in flood heights of—					
						Every spring.		1904		1844			Every spring.		1904		1844	
	From—	To—				Total.	Land.	Total.	Land.	Total.	Land.		Total.	Land.	Total.	Land.	Total.	Land.
Grafton	Mouth	Kampsville Dam	31.50	3,720	2,710	19,900	13,470	41,600	35,170	47,200	40,770	2,170	13,900	8,010	27,460	21,570	31,190	25,300
Pearl	Kampsville Dam	Mile 52.39	20.89	2,860	4,820	23,200	15,520	40,300	32,620	47,220	39,540	300	4,800	1,640	8,370	5,210	10,630	7,470
Valley City	Mile 52.39	La Grange Dam	26.11	2,640	5,480	29,600	21,480	52,160	44,040	61,520	53,400	2,670	14,000	8,690	21,000	15,690	26,060	20,750
Beardstown	La Grange Dam	Mile 108.63	30.13	2,900	12,820	50,200	34,480	72,300	56,580	81,400	65,680	7,950	33,800	22,950	49,530	38,680	56,460	45,610
Havana	Mile 108.63	Copperas Creek Dam	28.67	2,240	10,240	46,500	34,020	54,830	42,350	57,040	44,560	9,120	37,850	26,490	43,040	31,680	44,280	32,920
Pekin	Copperas Creek Dam	Peoria Lower Bridge	24.70	1,880	4,310	24,200	18,010	32,090	25,900	34,140	27,950	1,470	9,300	5,950	14,010	10,660	15,650	12,300
Peoria	Peoria Lower Bridge	Henry Dam	35.00	9,950	1,910	29,500	17,640	36,140	24,280	38,480	26,620	1,780	27,050	15,320	33,300	21,570	35,600	23,870
La Salle	Henry Dam	La Salle	27.40	2,300	7,050	23,600	14,250	29,320	19,970	30,980	21,630	6,140	21,350	12,910	26,780	18,340	28,380	19,940
Total	Grafton	La Salle	224.40	28,490	49,340	246,700	168,870	358,740	280,910	397,980	320,150	31,600	162,050	101,960	223,490	163,400	248,250	188,160

PART IV.

AGRICULTURE IN THE ILLINOIS RIVER VALLEY.

Although the Illinois River was one of the earliest highways of commerce, and some of the first cities of the State were built upon its banks, with a few important exceptions these settlements have not attained large growth. It is only where the railroads have crossed the river that important municipalities have grown up. The villages not having railroad connections have remained in population practically where they were at the time the western railroads were first built. For the most part, these cities, and indeed the villages, are well above the high water mark. The exceptions are the immediate water fronts of several cities, and a considerable portion of the city of Beardstown, which is located upon a knoll adjoining the river bank, which becomes an island in case of extreme flood. The exceptional floods invade the business districts of the city, covering the streets to a shallow depth. Therefore, so far as the cities are concerned, and the industries therein, the matters considered in this report are of relatively small moment. The river, its flow, its floods and its stages are of principal concern to the industries of farming and fishing. The relative importance of these two industries has an important bearing upon the control of river improvements. In the following pages we will endeavor to show the present status of agriculture, and in a separate part of this report will consider the matter of the fisheries.

GROWTH OF AGRICULTURE.

Agriculture in the bottom lands has been of comparatively recent development. Mr. Lyman E. Cooley, C. E., who has given much study to the river, describes it as follows:

"The character of these bottoms was described in the first official examination by Capt. Howard Stansbury in 1838. He describes the valley as from 1 to 5 miles wide, deeply overflowed in every freshet, filled with bayous, ponds and swamps, and infested with wild beasts; clothed with dense vegetation, and said it was 'a forbidden wilderness ever incapable of inhabitation by man.' General Wilson in 1867 gives his own description and quotes Stansbury, and he says, 'It may be true in part, but already cultivation has begun to encroach upon the higher bottom lands.' General Marshall in 1890 also described the bottom lands, their character, and says that 'cultivation has extended over the higher bottoms; in fact, it extends everywhere they can get in seed before the floods begin.' He says, 'At about the 12-foot stage, the sloughs, ponds, the lakes and the lower part of the bottoms are filled; at a 16-foot stage, 80 per cent of all the lands that are ever flooded, are already covered.'"

The bottom lands on the lower reaches of the river are higher than those further north, and were cultivated earlier, but until the construction of levees was begun, the cultivation was largely confined to the

higher ground covered with water for only a short time, or in some years not at all.

Although a few levees were built at an earlier date, the construction of levee districts as now existing, began only shortly prior to 1900. In 1904, at the time of the survey of the U. S. Engineers, less than half a dozen districts had been built. These being widely scattered, and most of them of small size, the interference to flood flow was not material. At the present time more than 40 per cent of the river valley has been reclaimed, and most of this work has been done since 1908.

LEVEES.

With but few local exceptions, the river follows the foot of the hills forming the west bank, the low bottoms lying to the eastward of the stream. The eastern bank is higher than the general level of the bottoms on account of the quick deposit of the sediment carried by the main stream in flood, as the rising waters pass landward. This provision of nature has been utilized to protect the farm lands from inundation by

FIGURE 20.

A New Levee Showing Extreme Irregularity of Much of the Dipper Work.

levees which border the low water edge of the stream 300 or 400 feet landward therefrom, and usually following the stream until an important tributary is reached, thence following the bank of the tributary to the eastern highlands. At some places where the thread of the river is in transit between the eastern and western highlands of the valley, levee districts have thus been formed on both sides of the main stream, but the greater number of districts lie to the east thereof.

The practice is common to construct these levees by dipper dredging, a floating dredge being used riding in a wet borrow pit or moat from which the excavated material is cast upon the bank forming a rather rough and irregular levee, and shown in the accompanying cuts, Figs.

20 and 23A. It is common practice to use a borrow pit about 60 feet in width with a 10-foot berm between the borrow pit and the toe of the levee. The levees usually have a theoretical top width of about 6 to 8 feet, and combined side slopes of from 4½ to 5 on one. It is the practice to place the borrow pits on the river side of the levee and to leave a space of 200 feet more or less between the borrow pit and the low water river bank. The trees and brush upon this space are left in place to serve as a "wave break" for the protection of the levee.

A few of the smaller districts have no pumping facilities, but the great majority of the acreage is drained by pumps which operate at such seasons of the year as the river may be above the desirable water plane in the district. Many of the sloughs, ponds and lakes are drained and farmed, but a portion of the lowest of these depressions is commonly used for the storage of excessive rainfall.

GROWTH OF LEVEE DISTRICTS.

Fig. 21 is a scale drawing of the river valley and serves to picture the growth of the levee districts and the extent to which they have encroached upon the flood water plain of the river. Separate diagrams are shown illustrating the conditions in 1904, practically at the beginning

FIGURE 21A.

Within the Levees. A Newly Reclaimed District.

of levee construction, and the year of one of the greatest floods that has occurred upon the river. The black area indicates the extent of water surface in flood. Up to 1908 a few additional districts had been built. The third plat indicates the conditions in 1913, at which time another greater flood occurred, caused by the edge of the storm which did such tremendous damage in Ohio. The fourth diagram represents the condi-

SHOWING AREA SUBJECT TO FLOOD IN 1904

RESTRICTION OF FLOOD CHANNEL IN 1908

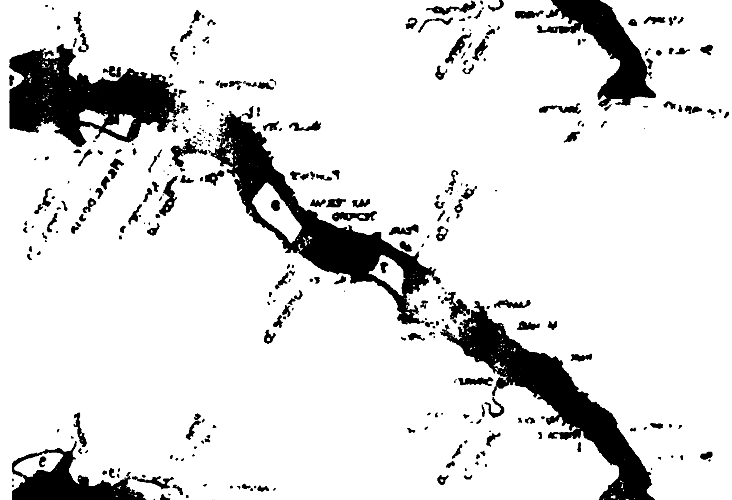
LIST OF LEVEE DISTRICTS

1	Private	17	[illegible]	33	[illegible]
2	[illegible]wood	18	[illegible]	34	[illegible]
3	Private	19	[illegible]	35	[illegible]
4	[illegible]	20	[illegible]	36	[illegible]
5	[illegible]	21	[illegible]	37	[illegible] Private
6	[illegible]	22	[illegible]	38	[illegible]
7	[illegible]	23	[illegible] Private	39	[illegible]
8	[illegible]	24	[illegible]	40	[illegible]
9	Big Swan	25	[illegible]	41	[illegible]
10	Scott County	26	[illegible]	42	[illegible]
11	[illegible] Private	27	[illegible] Creek	43	[illegible]
12	[illegible]	28	Langellier	44	[illegible]
13	[illegible]	29	[illegible]	45	[illegible]
14	[illegible] Creek	30	[illegible]	46	[illegible]
15	[illegible] Private	31	[illegible] Private		
16	[illegible] Lake	32	Thompson Lake		

* [illegible] protected by levee

NOTE

Part of district No 7 leveed before 1904. Districts No [illegible] protected from low floods only prior to 1913



tions during the summer of 1914, with districts under construction completed. The last diagram shows the conditions as they may exist in the comparatively near future when all the districts now projected are completed.

It will be observed that in the lower one-quarter of the river valley the flood plain width has been reduced nearly 80 per cent.

EFFECT UPON FLOODS AND FISHERIES.

It need hardly be stated that the restriction in the flood plain through the construction of levees must tend to produce greater flood heights under like flood flows. The reclamation of this land, and particularly the lakes, has been detrimental also to the breeding and taking of fish, an important industry upon this stream.

The extent of the effect upon floods and the detriment to the fisheries will be hereinafter discussed. Our purpose in this section of the report is to show to what degree the agricultural industry is important as having a bearing upon remedies that may be applied to the control of the river.

INSPECTION OF DISTRICTS.

Although at present the State law requires a permit for the construction of levees and other structures upon public waters, and the most recently constructed districts have filed plans with the Rivers and Lakes Commission, the record of the operations within the valley was by no means complete, and to secure the data needed to determine the effects upon the levees, stream flows and other matters, and to determine approximately the commercial importance of agriculture within this valley, a careful investigation was found to be necessary.

This examination included a three days' inspection of the stream from La Salle to Grafton, made by the undersigned in company with the Rivers and Lakes Commission and the Fish and Game Commission. Following this inspection, our representative examined nearly all the levee districts in person, first visiting all the county seats where the records of levee operation were on file, obtaining information on file at the court houses, calling upon many district commissioners, bankers and business men, and interviewing engineers who had designed or worked upon the levee districts. Having completed this examination and having completed a list of the districts constructed and in progress of construction, he returned to Peoria, and by motor boat again passed down the river, stopping at each pumping plant along the way for the purpose of noting pumping equipment and supplementing information regarding the levee districts, where lacking.

The data obtained from the county clerk's office usually included the boundary of the district as described in the court decree organizing the district, alterations of district made by subsequent decrees, acres assessed in the assessment roll, the area of each district if given, although this was usually not on record, the most recent annual assessments, the total of special assessments since the organization of the district, the amounts paid out for original construction, and the names of the commissioners and engineers. The condition of the records differed mate-

rially in different counties. Most of the counties have special drainage record books in which matters pertaining thereto are segregated. In some counties the records are in the miscellaneous records; some of the records are apparently incomplete.

PRINCIPAL DATA OF LEVEE DISTRICTS.

Table No. 11 herewith summarizes the principal data concerning all the levee districts of record, all the private districts that could be located, and so far as we could ascertain by inquiry locally, and from the engineers interested in such matters, the projected districts.

For convenience, the districts are designated by name and referred to by number on Fig. 22 which indicates location. In general, the numbers are consecutive from the mouth of the river upstream.

A large number of the figures on acreage within the several districts were obtained from the engineers. A few values were found on maps or reports on record, and some were obtained by planimeter from maps of the districts or from maps of the Illinois River valley. Areas determined by planimeter are so indicated on the summary sheet.

So far as possible, the areas under cultivation in each district were estimated. This was not possible in the case of all districts. The totals at the bottom of the page, Table 11, assume that the districts upon which no figures were obtained vary as the average of the districts where estimates were practicable. Apparently about two-thirds of the acreage is now in cultivation, and about 90 per cent is susceptible to agriculture. The waste land for the most part is in the beds of deep lakes or occupied by the ditches and structures necessary for drainage and the utilization of the land.

Areas in cultivation and acres cultivatable, we obtained by talking with persons familiar with the ground and comparing the same with the assessed area which would usually be equivalent to the useful land.

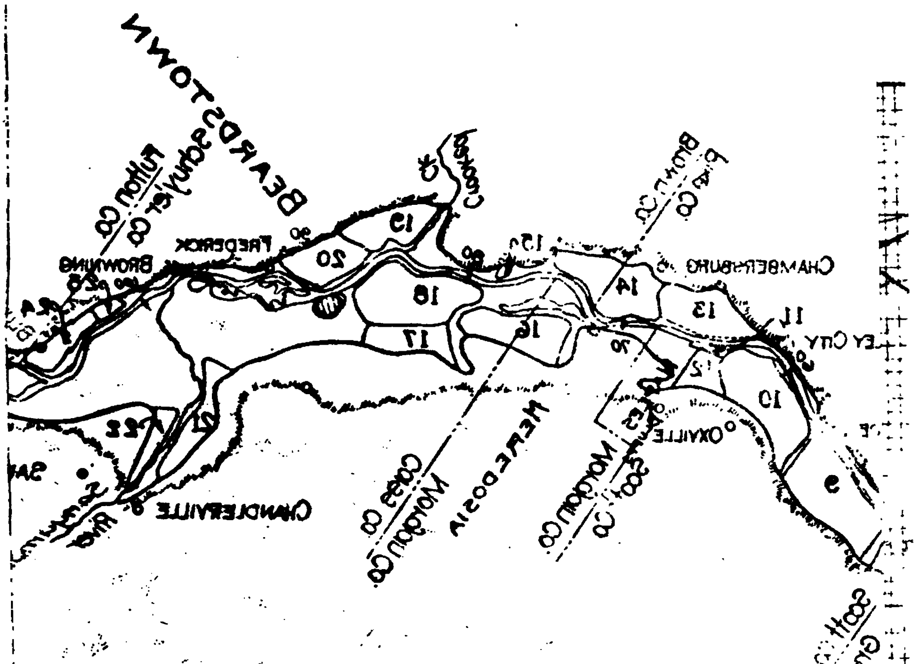
INHABITATION.

The number of dwellings and inhabitants within each district was obtained from people familiar with the area. For districts with less than ten dwellings, the reports are probably fairly accurate, but for districts of greater population, many of the answers received were evidently wild guesses. The results as a whole must be considered as approximate.

DATES OF CONSTRUCTION.

In studying the behavior of floods during the last ten years, it was important to know the extent of river valley developments, and to this end careful inquiry was made as to the date of beginning and completing each levee. These dates were usually obtained from the engineers in charge, or from the commissioners of the district. In nearly all instances the dates were certain, and are probably as accurate as indicated by the figures in the tabulation.

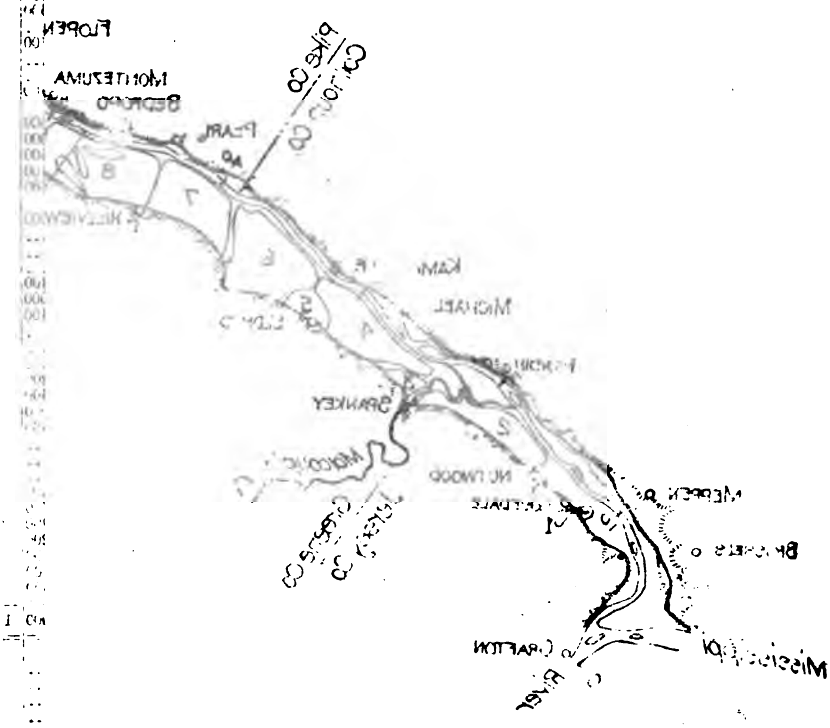
High water elevations as shown in the table are taken from all available gage readings on the river with interpolations between gages.

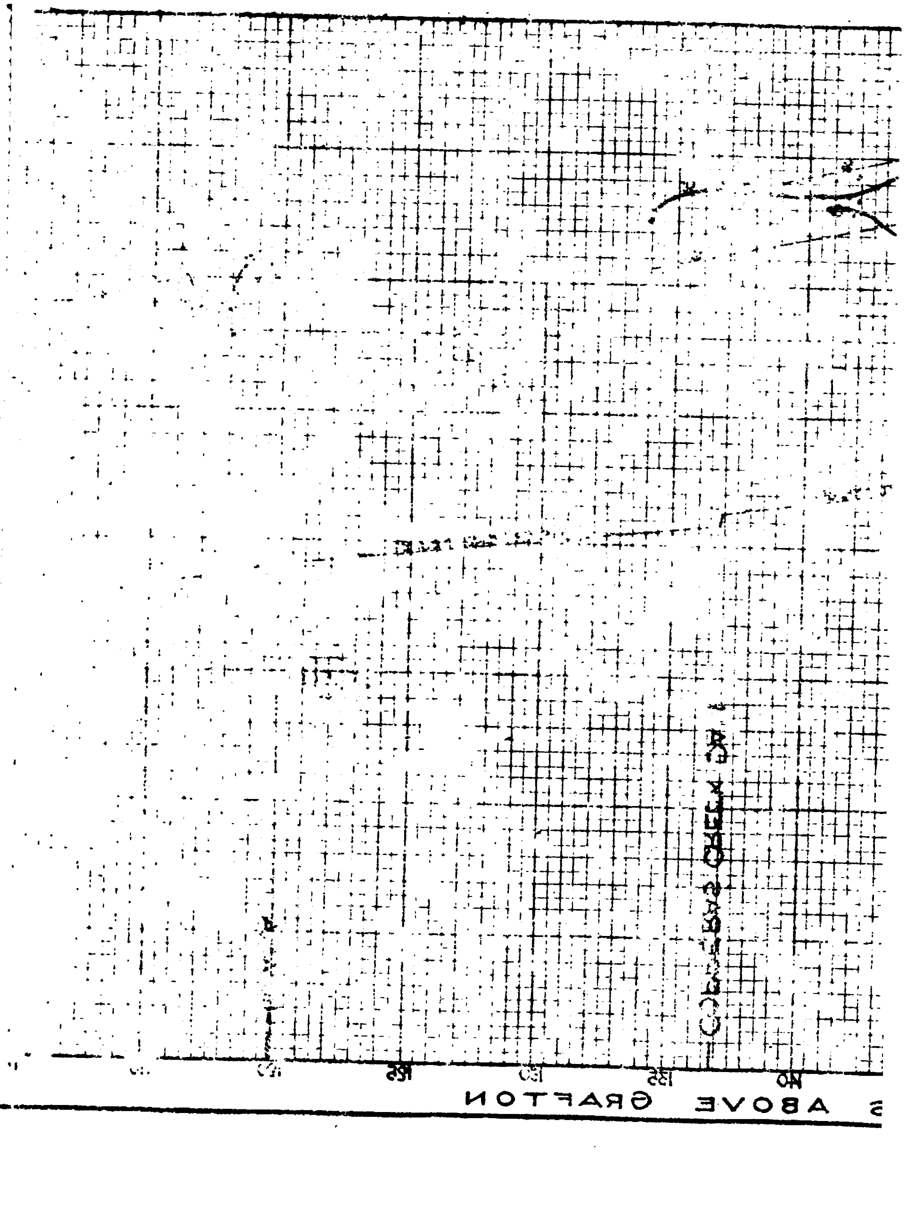


LIST OF LEVEE DISTRIC

1	Private	17	Valley	33	Mud
2	Nutwood	18	South Beardstown	34	Duk
3	Private	19	Crane Creek	35	Spr
4	Eldred	20	Coal Creek	36	Ban
5	Private	21	*Clear Lake	37	Curr
6	Keachor-Fairbanks	22	*Lynchburg & Sangamon	38	Pek
7	Hartwell	23	Hamm-Private	39	Peo
8	Hillview	24	Big Lake	40	Eas
9	Big Swan	25	West Point-Proposed	41	Pro
10	Scott County	26	W. Matanzas-Proposed	42	Part
11	H.& C. Oakes-Private	27	Otter Creek	43	Pro
12	Mauvaisterre	28	Langellier	44	Pro
13	Anderson Lake-Proposed	29	Lacey	45	Pro
14	McGee Creek	30	Spoon River-Unorganized	46	Hen
15	Kerr-Private	31	Shulte-Private		
16	Meredosia Lake	32	Thompson Lake		

★ Map shows portion of district protected by le





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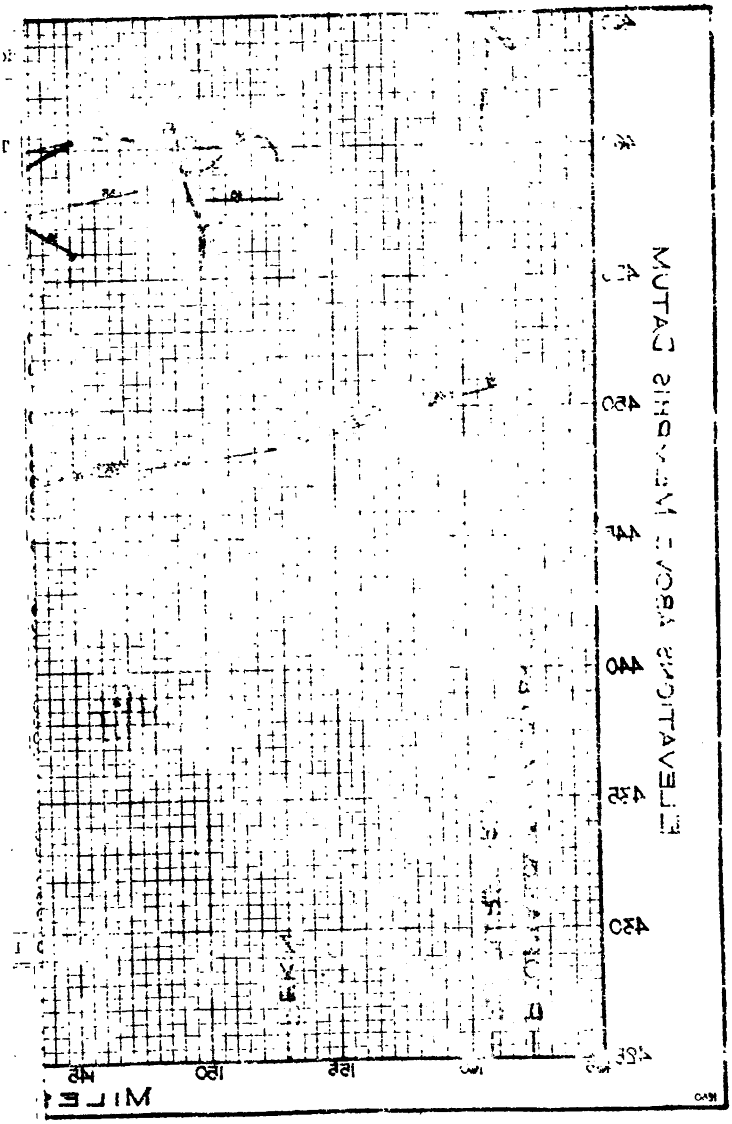
135
140
ABOVE GRAFTON



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LEVEE CRESTS.

The elevations of the levee tops were obtained from the engineers for the districts in the great majority of cases. In a few cases this information could not be secured. We were advised that in some districts the levees had settled and washed so that the effective height is less than the standard profile. It is said that there are instances where, owing to lack of inspection, the construction did not follow the plan at all places. It has been the usual custom to fix the standard profile for the levee top on a line paralled to the river, horizontal, that is, without allowing for the fall of the stream. As much of the work was done by dipper dredges, the profile was usually not accurately followed, but an effort was made to place sufficient excess material to allow for settlement, a reasonable amount of wash, and the ordinary inequalities of dipper dredging. In some of the districts the tops of the levees were smoothed with a drag after the materials had settled and weathered.

SECOND INVESTIGATION.

After the examination above described, and following a platting of the results, a comparison with flood profiles disclosed the need for further information. Accordingly, a second trip was made by launch from Peoria to the lower end of the levee system in February, 1915, at which time the river was in moderate flood and it was possible to land on the levees directly from the launch or by means of a rowboat.

The investigator was equipped with a wye level. He landed usually at three places on each levee; near the head, in the middle and near the lower end of each district. At each place he recorded the elevations of the levee tops for several hundred feet upstream and downstream from the point at which a landing was made.. The levels were referred to the water level in the river prevailing at the time, and were reduced to Memphis datum by noting the stage of the river as indicated by the gages passed during the trip, interpolating between gages where necessary.

The result of this examination is shown upon Fig. 23 on which is indicated the individual observations as to height, and a profile of each levee showing the general average height at various places between the head and foot of same. The standard grade for each district is indicated on the same drawing as reported by the engineers of the districts or others possessed of the information.

The extreme variation in height noticeable in some of the levees is usually accounted for by some special circumstance, as the utilization of a railway embankment often materially higher than necessary to give the standard grade of protection, or in one or two cases, the inequalities resulting from work in increasing the height of the levees only partially completed.

We were further advised that in some of the cases where the height appears to be much above the standard grade, this condition is accounted for by the use of a dipper dredge in the construction of the levee, and the necessity for excavating sufficient material to float the dredge, the excess excavation being thrown on the top of the embankment.

Most of the extreme low points noted occurred at pumping stations for short distances, the levees being left at low grade probably for convenience in handling fuel from barges, doubtless with the thought that the height could be quickly increased in case of need. A number of other low points are occasioned by road crossings where the standard was not maintained for similar reasons.

Although a slight error is introduced by referring these levees to Memphis datum by comparison with water levels, the extreme irregularity in these levee profiles would hardly seem to have warranted the connection of each levee to a standard benchmark. To have done so would have been impossible with the means available for this report.

FIGURE 23A.

A Typical Pumping Station. Note, also, the Irregular Dipper Dredge Levee.

PUMP CAPACITY.

Pumping capacities where possible, were secured from the designing engineers. In some cases it was necessary to compute the capacity from the sizes of the pumps, and where this was necessary, it was done on the assumption of a discharge velocity of 10 feet per second.

COST OF DISTRICTS.

The figures as to cost were obtained from the special assessment record and the amounts paid out as on record, checked by consultation with commissioners and interested parties, to determine whether all assessments levied had been found, whether funds had been privately subscribed before any assessment was made, and whether amounts had been assessed but not used. On the whole, the costs are thought to be fairly accurate. For private districts, costs were hard to obtain as they are not on record. Some low values shown are for incomplete districts, particularly those not equipped with pumps.

ASSESSED VALUATION.

The assessed valuations are based upon the record for 1913. However, property is not divided on the limits of levee districts so that it was impossible to determine the exact assessed valuation. The method used was to refer to a map showing the boundaries of the district taken from the assessor's record or from the collector's record, the assessed value of each piece of property lying entirely within the district, and to make a fair division where properties overlap the boundary.

FULL VALUE OF PROPERTY.

The full value of land within districts was estimated by talking with landowners, bankers and people familiar with the areas. In general, the landowners were inclined to place a higher value on the land than bankers and disinterested parties. Most of the bottom land within the district is equivalent in productivity to the very best Illinois farm land; but the cost of pumping and maintenance, the possibility of damage from high water, and the fewer improvements due largely to fear of overflow, are factors tending to reduce the value of the land below that of the less productive upland. The total value of the land in each district was computed from the average value per acre.

IMPROVEMENTS AND CONDITIONS.

Many of the districts visited had but few permanent improvements. The larger number of districts are comparatively new, and many are practically beginning their productive existence. For these newer districts the dwellings are principally temporary in character. Nearly all of the districts have good substantial pumping stations. There are very few improved roads. Where levees can be used for roads, fairly good highways exist, but in the bottoms considerable work is needed to put them in condition for use at all seasons.

As would be expected, the older districts have the best improvements, especially those adjacent to Beardstown.

CONDITION OF LEVEES.

One criticism, not applicable to all districts, is the lack of attention paid to the levees. The construction by dredge is undoubtedly the best method to employ for high levees, but this leaves the levees with the appearance of a miniature mountain range. The location of much of the levee work makes it difficult to obtain thorough and continuous inspection; and in one instance reported, the inequalities in the elevation of the levee top gave the district 2 feet less protection than the plans intended, or the average material handled made possible. It is probable that similar conditions exist in other districts.

As a rule, the levees are allowed to be covered with a rank growth of weeds. On one of the private districts the owner proposes to fence his levees and to pasture them. This would keep the surfaces exposed to view so that damage from burrowing animals or from other causes, would be readily noticed and the presence of cattle would tend to drive away

pests. When the danger from poorly kept and poorly inspected levees is considered, this plan would seem to be worthy of consideration by all landowners.

ESTIMATED PRODUCTIVITY OF AGRICULTURAL LANDS.

So far as we were able to determine, there are no statistics from which the annual value of the crops can be computed for the Illinois River Valley. The most definite figures practicable are apparently based upon the improved acreage and the average yields so far as they may be determined. At the time that we examined the levee districts, an effort was made to secure as accurately as possible, the average crop yield on each. To this end, those likely to be most familiar with the local facts were consulted, including farmers, drainage commissioners, engineers, and where possible as a check, bankers in the adjacent towns. Corn is the staple crop on the bottom lands, but wheat is also produced. Stock raising has not yet become extensive.

It is believed that fairly accurate figures were obtained from about one-half the levee districts in crop. Most of the corn yields range from 40 to 90 bushels per acre, and the wheat yields 20 to 40 bushels. Those best informed are of the opinion that the bottom lands properly farmed should yield 50 to 60 bushels of corn per acre over a period of years. At the present time, the price of corn is abnormallv high. The estimates of yield that we secured were based upon a more normal price of 50 cents for corn, with other grains in proportion. The crop yields per acre for fourteen districts, aggregating 61,000 acres as estimated by the best informed local people ranged from $18.00 to $50.00 per acre, the latter figure covering a small district, and averaged $26.20 per acre in cultivation. Some large well improved tracts are said to produce $30.00 to $35.00 per acre, based upon 50 cents for corn.

In 1914 the farmers received an average price of 70 cents for corn and 87 cents for wheat. At these prices large tracts yielded $30.00 to $45.00 per acre.

At the present time about 113,000 acres are in cultivation or will be ready for cultivation this year. At $27.00 per acre, the annual yield would be $3,050,000.

The land subject to cultivation is estimated at 157,000 acres. It is believed that within the next few years this land should be improved so as to produce about $33.00 per acre at average prices. This is equivalent to $5,200,000 per annum.

With all districts now projected, assuming that the cultivable land will be in about the same proportion to the leveed area as in the districts now improved, the total cultivated area in the valley would approximate 200,000 acres, which, if so improved as to produce a gross return of $33.00 per acre, would produce a gross yield of $6,600,000 per annum.

UNLEVEED LANDS.

The acreage capable of crop without levees in that portion of the valley where levees do not now exist, is comparatively small, bordering the extreme high water line fairly closely. Below the La Grange dam, except for the land close to the mouth of the river, this acreage is a

narrow irregular strip on the slope of the hills. Above the La Grange dam there are 178,900 acres unleveed below the plane of the 1844 flood (land and water) and there are 45,600 acres lying above the plane reached in the flood season every year since 1900. There are 22,700 acres flooded only one year in three. There are about 35,000 acres of land which has been free from water by May 1 since 1900, two years in three. A large part of this land has not been flooded since 1844.

By no means all of the land is cleared that could be farmed, and no estimate is practicable as to the acreage in crop. If it is assumed that the whole of the 35,000 acres produces an average of $15.00 per acre, the yield of this land would be about $500,000 per annum.

SUMMARY OF AGRICULTURAL VALUES.

To sum up, therefore, in round figures, about 170,000 acres or about half the bottom land acreage below La Salle has been leveed at a cost of $30.00 per acre, or slightly over $5,000,000; that these lands today are valued at nearly $20,000,000, that they produce annually about $3,000,000, and when fully cultivated should produce about $5,000,000 per year.

When districts now projected are fully cultivated, the total yield of the leveed lands of the river should approximate over $6,000,000 per annum.

The gross return from the unleveed lands above the La Grange dam probably does not exceed $500,000 per annum.

PART V.

THE FISHERY OF THE ILLINOIS RIVER.

It is a fact not generally known that the fishery of the Illinois River is the most important river fishery of the country, excepting only the salmon industry of the Pacific Coast, and this is not, strictly speaking, a river fish.

In the last U. S. Census, which covered the calendar year 1908, the fish taken commercially from the Illinois River totaled 23,896,000 pounds, returning $721,000 to the fishermen, at about three cents per pound. The river produced 62 per cent of the fish taken in this State, and over 10 per cent of the fresh water fish of the United States.

The industry has grown from about 6,000,000 pounds taken in 1894, to the maximum of nearly 24,000,000 pounds in 1908, since which time the catch has declined very rapidly. This growth and decline is attributable to a number of causes, among which may be mentioned the introduction of the German carp, the increase in waters brought about by the Chicago Drainage Canal, the effect of the accompanying sewage thereof, and the closing and reclaiming of the lakes which has taken place very rapidly since 1900 through the leveeing of lands and the isolation of such waters by hunting and fishing clubs. These causes, some tending toward increase and others toward decrease, are so interrelated and their combined effects are so important to the permanency of the fish industry as to warrant careful study to the end that, so far as possible, the beneficial conditons may be promoted, and the detrimental conditions relieved in so far as this is consistent with the public welfare. It will be our endeavor to throw such light upon these matters as is possible with the existing data.

GAME FISH.

The Illinois River bottoms are today, and have long been considered, the best game fishing grounds of the State, and also the best hunting grounds for water fowl, and while retention of these recreation grounds is warranted in so far as consistent with the development of the country and its citizens, the commercial importance of the fishery is concerned with the so-called game fishes to a relatively minor degree, for although they bring the highest price, the weight taken is relatively small. The game fishery, however, is of great importance to the sportsmen of the State, and is an important source of revenue to the towns along the river. Experienced observers estimate that the local communities receive approximately as much money by reason of the visiting fishermen as they do from the commercial fisheries.

FOOD FISH.

The principal value of the catch is in the German carp, and until recently, the buffalo fish, neither of which is extensively used at present

by American born people, but which furnish an important and cheap food to people principally of foreign birth in the larger cities. Most of the Illinois River fish is shipped to Chicago and New York.

Taste in this regard is doubtless a matter of education, for to the European who understands the cookery of the carp and has become accustomed to it through generations of use, it is regarded as a great delicacy among all classes of people, even the nobility. In Germany particularly, carp farming is well established, as an independent industry, and has been practiced for centuries in much the same way that poultry is handled upon the American farm.

As yet, the food fish does not compel the price commensurate with its value as a food, carp selling in the American market at from 1½ to 5 cents per pound, depending upon the season, and averaging about 3 cents in return to the fishermen as compared to 10 to 12 cents for bass and pike-perch, and about half as much for whitefish and catfish. The German wholesale prices for carp are about equivalent to the American price for bass, or from four to five times the present price of carp in this country. It will not be sufficient therefore, to measure the future possibilities of the Illinois River as a fishery by the present price of its product. The fish produced are certain to become more valuable, and particularly the so-called food fish.

TABLE NO. 12—TABLE SHOWING TOTAL FISH CATCH—ILLINOIS RIVER—1894-1908.

Year.	Agency reporting.	*Pounds of fish.	Cents per pound.	†Value to fishermen.
1894	United States Fish Commission	6,037,378	2.7	$162,450
1896	Illinois Fishermen's Association	7,252,811	2.85	207,687
1897	Illinois Fishermen's Association	9,703,798	2.88	279,482
1899	United States Fish Commission	14,006,866	....	....
1899	Illinois Fishermen's Association	11,205,516	3.22	362,246
1900	Illinois Fishermen's Association	11,899,865	3.27	388,876
1903	United States Commission	10,779,582	....	....
1906	Illinois Fish Commission	16,149,076	....	....
1907	Illinois Fish Commission	14,739,000	....	....
1908	Illinois Fish Commission	19,270,000	....	....
1908	United States Bureau of Fisheries	23,896,000	3.02	‡721,000

* Pounds includes fish only.

† Value includes turtles and miscellaneous products which are not weighed; this affects price per pound as given, slightly. Mussel shell products excluded in all figures.

‡ Computed by deducting shells and pearls.

GROWTH IN PRODUCTION.

Table No. 12 shows the total fish catch, together with the value thereof, upon the Illinois River for such years as statistics are available. It includes the period 1894 to 1908. The table shows the agency gathering the statistics in each year for which figures are given. It will be noted that in certain years as in 1899 and 1908, different agencies present figures not entirely in agreement. The figures of the U. S. Fish Commission and the U. S. Bureau of Fisheries seem to be somewhat larger than the figures of the Illinois Fishermen's Association and the Illinois Fish Commission in the years where comparisons are practicable. All these figures refer to fish taken for sale, no account being taken of the very small catch used by the fishermen. All the statistics

are primarily based upon fish shipments, and in view of the fact that there is more or less shipping from the minor to the major markets on the river, more or less duplication is probable in all the statistics herein given. It is believed that the statistics of the local Illinois associations probably represent the true fish catch more nearly than statistics prepared by the U. S. agencies.

Table No. 13 shows the relation of the Illinois River yield to that of the State and to the United States for the year 1908, in accordance with the figures of the U. S. Bureau of Fisheries as contained in the Census of 1910.

TABLE NO. 13—GENERAL STATISTICS OF FISHERIES—ILLINOIS RIVER—STATE OF ILLINOIS AND UNITED STATES.

United States Census for year, 1908.

Value of Fish and Mussel Products (to Fishermen)—	
United States	$8,329,000
State of Illinois (16 per cent of total United States catch)	1,388,000
Illinois River (62 per cent of State, 10 per cent of United States)	860,000

Statistics for Illinois River—		
Total value of catch		$860,000
Value excluding mussel products		721,000
Persons employed (exclusive of shoremen)—		
Proprietors	1,504	
Salaried	6	
Wage earners	987	
		2,497
Capital employed		$551,000

MEN AND CAPITAL.

The table also shows the statistics of persons engaged in the fisheries together with capital invested according to available statistics.

In 1908 more than half the fishermen of the State were on the Illinois River (2,500 persons), and nearly two-thirds of the total capital employed in fisheries, ($551,000).

TABLE NO. 14—TOTAL FISH CATCH—HAVANA MARKET.

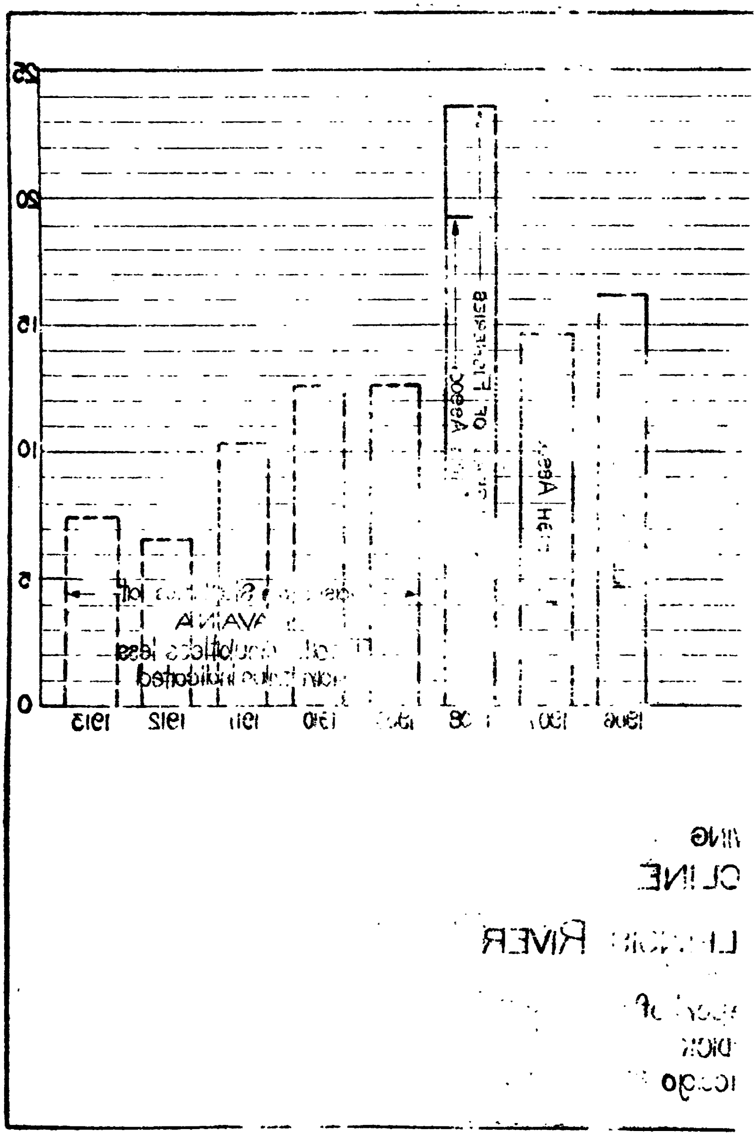
Year.	Pounds.	Per cent of total catch on river.	Authority.
1896	1,573,298	21.7	Illinois Fishermen's Association.
1897	1,600,183	16.5	Illinois Fishermen's Association.
1899	1,830,291	16.3	Illinois Fishermen's Association.
1900	1,368,010	11.4	Illinois Fishermen's Association.
1907	2,700,000	18.4	Illinois Fish Commission.
1908	3,800,000	19.7	Illinois Fish Commission.
Average	....	17.3	
1908	3,066,658	....	R. E. Richardson.
1909	2,223,794	....	R. E. Richardson.
1910	2,221,930	....	R. E. Richardson.
1911	1,803,724	....	R. E. Richardson.
1912	1,181,151	....	R. E. Richardson.
1913 (to October 31)	1,293,563	....	R. E. Richardson.

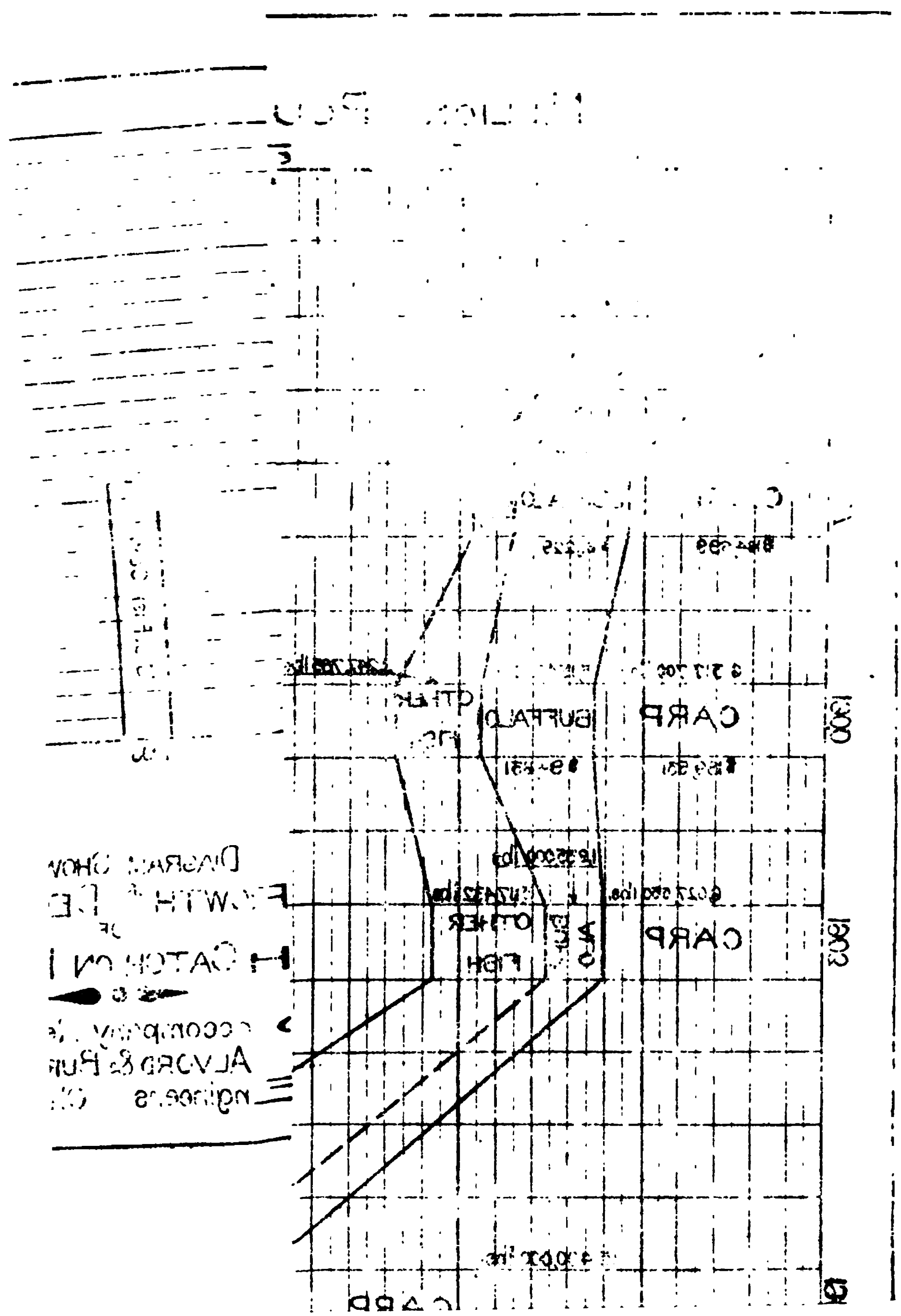
NOTE.—1,593,000 pounds average 1896 to 1900 inclusive.

STATISTICS SINCE 1908.

There are no figures covering the entire river for the years subsequent to 1908. The only figures that we were able to secure concern the shipments from Havana, one of the most important fishing points on the river. Table No. 14 shows these statistics for the years 1908 to

FIGURE 24.





1913 inclusive, as collected by Mr. R. E. Richardson of the State Biological Station, Havana. For convenience in comparison, the Havana yields from the years 1896 to 1908, as reported by the Illinois Fishermen's Association and the Illinois Fish Commission, are stated in the same table, together with the percentage that the Havana yield bears to the total fish catch of the river, as reported for those years by those agencies. From 1896 to 1908 Havana has produced not less than 11 per cent, and not more than 22 per cent of the Illinois River yield, and has averaged 17.3 per cent.

DIAGRAM OF TOTAL FISH YIELD.

Fig. 24 is a diagrammatic representation of the total yield of fish on the Illinois River from 1894 to 1913. The last five years have been based upon the assumption that the shipments at Havana were equivalent to 17.3 per cent of the total yield of the river. This probably makes the apparent total yield somewhat too large, as the fish production at places further downstream suffered to a much greater degree during this period than have the Havana fisheries.

This diagram serves to illustrate the gradually increasing yield in 1894 to 1908 and its subsequent rapid decline.

YIELD OF VARIOUS SPECIES.

The reports of the Illinois Fishermen's Association are quite specific in regard to the kind of fish taken. From these data Fig. 25 has been prepared which shows the size of the catch for the leading varieties for the years 1894, 1897, 1900 and 1903, with the total catch for these years, and the same facts from the U. S. Fishery statistics for the year 1908 so far as they differentiate as to kind. In the last named year the figure for the total and for carp only are given. The catch of buffalo fish has been estimated from figures by Mr. R. E. Richardson, showing the relation between carp and buffalo for that year at Havana.

It will be observed that up to 1908, the increase in the yield of the river is largely accounted for by the increase of the carp. The yield of buffalo fish, which was formerly the principal food fish of the Illinois River, gradually decreased up to 1908. Since 1908 the buffalo fish has almost wholly disappeared above the lower dam.

It will be observed that the yield of varieties other than buffalo and carp also gradually increased up to 1908. No later statistics are available, but the subsequent yield is known to have greatly decreased, as evidenced by the estimated totals in the diagram previously referred to.

FISH PRICES.

It will be very useful in correctly interpreting the importance of the Illinois Fishery, and especially in comparing it with foreign statistics, to present the data on local prices together with similar prices abroad. This information serves to account for the large returns reported from European fish farms, and they further serve to show the future possibilities of the Illinois River Valley in the way of revenue produced by the fisheries.

FIGURE 25A.

Fish Market at Havana.

Table No. 15 shows the average German prices for carp from 1891 to 1905, both wholesale and retail. Table No. 16 shows the variations in the German price during the months of the year 1909.

TABLE NO. 15—YEARLY AVERAGES OF GERMAN PRICES FOR CARP, IN CENTS PER POUND, WHOLESALE AND RETAIL, BERLIN, 1891-1905.

Year.	Whole-sale—alive.	Whole-sale—in ice.	Retail.	Year.	Whole-sale—alive.	Whole-sale—in ice.	Retail.
1891	16.7	9.6	18.0	1900	15.0	10.4	18.0
1892	17.6	9.8	19.1	1901	15.0	11.0	18.7
1893	15.1	9.9	18.2	1902	14.4	10.3	18.2
1894	15.7	9.9	18.4	1903	15.0	10.9	18.4
1895	16.3	9.7	17.9	1904	15.9	10.4	19.0
1896	15.0	10.0	17.6	1905	15.5	12.3	19.9
1897	16.8	10.1	18.5				
1898	14.2	9.9	18.2	Average	15.53	10.06	....
1899	14.8	10.7	18.1				

Live carp sells at prices 54 per cent higher than dead.

TABLE NO. 16—WHOLESALE PRICES FOR CARP, BY MONTHS, FOR 1909, AT THE FISH AUCTIONS IN THE CENTRAL MARKET HALL, BERLIN.

Month.	Alive—cents per pound.	Dead—cents per pound.	Month.	Alive—cents per pound.	Dead—cents per pound
January	11.2	7.8	August	16.7	12.2
February	11.1	10.5	September	18.5	11.4
March	12.1	12.5	October	16.4	11.8
April	17.9	11.1	November	15.4	11.4
May	23.5	11.4	December	19.1	13.6
June	22.5	12.3			
July	....	....	Average	16.7	11.5

Live carp average 45 per cent more than dead.

Table No. 17 shows the average price per pound paid to the fishermen of the State of Illinois in the census year 1908, for fish of the principal varieties caught.

TABLE NO. 17—CATCH VALUE AND PRICE PAID TO FISHERMEN.

Principal Illinois fishes—figures represent total for the State—United States Census, 1908.

	Pounds.	Dollars.	Per pound—cents.		Pounds.	Dollars.	Per pound—cents.
Black bass	530,000	$ 57,000	.107	Paddle-fish	402,000	$12,000	.029
Sunfish	1,714,000	31,000	.018	Yellow perch	238,000	12,000	.05
Buffalo	3,042,000	117,000	.038	Pike and pickerel	14,000	1,100	.078
German carp	21,642,000	574,000	.026	Pike perch	14,000	1,500	.11
Catfish	2,044,000	96,000	.047	Sturgeon	178,000	6,500	.036
Crappie	1,281,000	35,000	.027	Suckers	281,000	6,400	.023
Dogfish	1,370,000	18,000	.013	Lake trout	150,000	13,000	.086
Sheepshead (drum)	666,000	20,000	.03	Whitefish	14,000	800	.057
Lake herring	598,000	28,000	.047				

Table No. 18 illustrates the variation in average wholesale price of carp in Havana, Ill., and New York, with the retail price in New York for the calendar months of 1914.

TABLE NO. 18—WHOLESALE AND RETAIL PRICES FOR CARP, HAVANA AND NEW YORK, RECENT YEARS (1908-1903)

Data furnished by John Dixon, principal fish dealer, Peoria, January, 1914.

Month.	Paid to fishermen, Havana.	Received by Havana shippers, on car lots to New York.	Price, retail to consumer, New York.	Month.	Paid to fishermen, Havana.	Received by Havana shippers, on car lots to New York.	Price, retail to consumer, New York.
	Cents.	*Cents.*	*Cents.*		*Cents.*	*Cents.*	*Cents.*
January	4 -5	5½-6	15 up	July	1 -2½	2½-4	About 15
February	5	7 -8	20 up	August	1½-3	3 -4½	About 15
March	3	4½	About 15	September	2 -3½	3½-5	About 15
April	1½-3	3 -4½	About 15	October	1½-3	3 -4½	About 15
May	1 -1½	2½-3	About 15	November	2½-3	4 -5½	About 15
June	1 -1½	2½-3	About 15	December	3½-5	5 -6½	About 15

MUSSEL SHELL INDUSTRY.

The statistics hereinbefore given do not include mussel shells or pearls. During the past ten years this has been an important industry on the Illinois, but has rapidly decreased of late, and is of relatively small importance at this time. It is regarded as an industry that attained large proportions through draft upon the accumulation of mussels of past years. The accumulation has been largely exhausted and the industry promises to be relatively unimportant henceforward.

FACTORS AFFECTING THE GENERAL WELFARE OF FISHES.

Before considering the reasons governing the recent increase and decrease of fish life in the Illinois River, it will make the discussion more

readily understood to outline as briefly as is consistent with a fair understanding, the general conditions under which fish life tends to increase and decrease. Mistaken ideas in this matter are believed to have been responsible for unwise experiments in the propagation of fishes. It is no more to be expected that fish will thrive in a pure water simply because it is water and pure, than that human beings should prosper if turned loose in the Desert of Sahara with the thought that they would prosper because air is available, and that it is pure air.

So far as the character of the water is concerned different varieties of fish thrive in waters of different clarity and cleanliness, but so far as concerns the fishes of the Illinois River, this stream below Hennepin seems to be sufficiently clear and clean for the needs of fishes that have lately inhabited these waters, particularly the fishes commercially important.

For prosperity there is required: first, water of sufficient purity to furnish the necessary oxygen; second, an abundance of food; third, extensive breeding grounds where the eggs may be laid and the young hatched with a minimum of molestation; fourth, shallow waters where the younger fish may develop and seek refuge; fifth, deeper waters where the more mature fish may lie, especially in winter; and, sixth, the means of travel from place to place as necessity arises in the life history of the fish, or as may be made necessary by increasing numbers and the scarcity of food.

The food for the wild fish is dependent upon the richness or fertility of the water in a respect similar to the fertility of soils in the growing of food for man. Sterile water has the same inability to promote aquatic life possessed by pure sand to produce agricultural products. Organic wastes as sewage, sufficiently diluted, furnish the basis for a whole train of invisible microscopic and minute animal and vegetable life, that, through numerous transpositions, furnishes the food for all varieties of fish and other water life as well, including the fishes feeding upon both vegetable and animal food, dead and alive.

Regarding the breeding and feeding grounds, Dr. Forbes makes the following statement:*

"We learned a good many years ago—and this fact was first established in Illinois—that virtually all our young fishes, whatever their adult habits may be, lived at first on the same kind of food; all which hatch in like situations and at approximately the same time, consequently, compete with each other when they first begin to feed. We have learned that this first food—the minute plant and animal life of the water, called its plankton—is produced almost wholly in the backwaters. Although flowing streams often carry an enormous quantity of it, this mainly perishes presently in our great silt laden rivers. When, as in very low water in midsummer, the contributions from the backwaters are reduced to a minimum, or perhaps wholly cut off, the plankton of the streams also falls off to little or nothing. Left to itself, indeed, even so slow a river as the Illinois, would virtually empty itself of plankton in a little while. The fish producing capacity of the stream is thus proportionate, other things being equal, to the extent and fertility of the backwaters accessible from it and contributing to it at the hatching time of fishes. The plankton content of a stream at that time is in fact an excellent index to the productive capacity of the waters as a whole."

* The work of the Illinois Biological Station, read to the Central Branch of the American Society of Zoologists at Iowa City, April 8, 1910.

"There is a notable harmony between time of highest flood in our great rivers, the spawning time of the bulk of our fishes, and the climax period in the development of the plankton. All coming together or following one another in quick succession as they normally do, conditions are as favorable as possible for a large stock of young fishes. The longer the period and the larger the scale of the spring overflow, the better is the prospect for a heavy annual contribution to the population of the stream. To this, no doubt, is due the fact, clearly indicated by our recent river work, that the plankton product of the Illinois system has been greatly increased by the opening of the drainage canal from Lake Michigan and the consequent raising of the average level of the river by about three feet, this rise of river level, of course, resulting in a very widespread and longer continued overflow."

The welfare of fish life further requires the deeper waters, not less than four or five feet, and perhaps deeper, well below the reach of ice, in which fish may lie, particularly during the winter. These places must be of sufficient extent in proportion to the amount of aquatic animal life, so that sufficient oxygen will always remain available. Doubtless the deep places in the river may be utilized for this refuge where the current is sufficiently slow, but to make such refuge fully useful, the lakes would necessarily be connected with the river at all or most seasons of the year. In the main the channel of the river, excepting its shallow borders, seems to be principally a road of travel from place to place. With the lakes reclaimed, the stream would be much less productive of fish life. The feeding and breeding grounds would be too small as compared to the deep water acreage.

The commercial fishes are caught in nets and seines in which the size of mesh is regulated by law, and certain requirements are exacted in reference to the returning of small fish to the stream. It is doubtless a fact that many fishes not taken are destroyed or so injured that they afterwards die in the operation of seining, and there are people who claim that such operations are detrimental to fish life. It is, however, held by those in position to know, that the taking of mature fish is beneficial to the fish yield and that there is probably no better means of securing the fishes of proper size than to seine or net them. It is undoubtedly true that the maximum yield will be secured by taking the fish immediately upon a reasonable maturity for much the same reason that beef animals are slaughtered at the age of two or three years, for like the farm food animals, the fishes mature most rapidly in early life, after which the gain in weight is small in proportion to the food consumed. Therefore, waters must be well fished to produce the maximum yield.

There are practical difficulties in the way of fishing the main channel of the Illinois River. This is especially true since the opening of the Chicago Drainage Canal, through the increased water levels occasioned thereby, and the flooding of trees and brush upon the banks. At present there are few places to land nets. The taking of fish is done principally within the lakes, although large quantities are caught in the river, using so called "nets," that is, fykes or hoop nets.

FACTORS AFFECTING THE INCREASE AND DECREASE OF FISHES.

With the above brief outline of the matters principally affecting fish welfare, it will be useful for our purpose to enumerate in so far as they

may be measured, the causes that have been operating recently, tending toward the growth and decline of the Illinois River fishery. Among these factors may be mentioned the introduction and growth of the German carp, the probable increase in fish food occasioned by the Chicago sewage, and the increased water levels and water acreages occasioned by the added flow from Lake Michigan. The factors tending toward reduced yields include the decreased breeding and feeding grounds brought about through the reclamation of the lakes and swamps, the decreased fishing grounds from the same cause, and the lakes owned and controlled by fishing clubs, and in the upper river, the only partly decomposed Chicago sewage which has driven the fish from the places where it is most objectionable.

Doubtless the most important factor in the increased fish yield prior to 1908, has been the German carp, and as there is some misconception in the public mind as to this fish and its value, it will be useful to quote somewhat at length from the statement of Dr. Stephen A. Forbes and Robert E. Richardson, contained in their volume, "The Fishes of Illinois," published by the Natural History Survey of Illinois. These men have closely studied the Illinois water life for many years. The quotation is as follows:

THE GERMAN CARP.

"The carp, which is native in China, was introduced into Europe as early as 1227 (Hessel), and was first brought to England at the beginning of the sixteenth century. The first successful introduction of carp into the United States was made in 1877, when R. Hessel, for the U. S. Fish Commission, brought 345 carp to this country. Of these, 227 were of the mirror and leather varieties, and 118 were scale-carp. All were put into ponds at Washington, D. C., and multiplied rapidly, more than 12,000 young being distributed in 1879 to more than 300 persons in 25 states and territories. From that time distribution rapidly increased until a few years before its final discontinuance in 1897.

"The introduction of carp into the waters of Illinois began with the first distribution (1879), and in 1880 scaled carp to the number of 800 were received from the U. S. Fish Commission. In 1881 and 1882 a total of 2,500 more carp were received and distributed by the Illinois Fish Commission, the distribution being mostly made in lots of only ten to a single person. In 1885 the first carp were planted in public waters, a total of 30,900 being set free in the Illinois, Fox, Sangamon, Des Plaines, Kaskaskia, Little Wabash, Big Muddy, and a few other streams. In 1886 the first large carp was caught in the Illinois River, a specimen 30 inches long being taken at Meredosia—probably escaped from some pond which had received a consignment from one of the early distributions. In 1887 about 16,000 more carp were planted in the public waters of the State. Between 1888 and 1890 reports of the capture of carp of considerable size increased in number, particularly from points along the Illinois River, and by 1892 this fish had multiplied to such an extent in the waters about Havana that more than 3,000 pounds were taken from Clear Lake in a single haul. A year earlier Bowles had begun to ship carp from Meredosia. By 1898 the multiplication and utilization of carp had increased to such an extent in this State that Captain John A. Schulte, of Havana, wrote: 'From the information I can get as an official of the Illinois Fishermen's Association from all points along the Illinois River, the carp have brought more money than the catch of all the other fish combined. Long live the carp!' Carp are now found very generally distributed over the State, being most common, however, in the Illinois River and in our other larger and more sluggish streams and lakes and bayous connecting with them. They are not yet very abundant in southern Illinois.

The carp catch of the Illinois River alone now reaches six to eight million pounds a year, valued at more than $200,000.

"Three races of carp are distinguishable: (1) the regularly-scaled form, which is nearest to the native type of the domesticated races; (2) the mirror carp, which has the body partly bare, with but two or three irregular rows of large scales along the back; and (3) the leather-carp, which is scaleless, with a thick, soft, velvety skin. Many local German races of carp, of no interest here, have been described. Although the first importation of carp by the U. S. Fish Commission contained a greater proportion of the mirror and leather races than of the scaled carp, the former did not thrive except under domestication, and today there are few mirror or leather carp living in a wild state in American waters.

"Carp prefer moderately warm water, not too deep, and with plenty of aquatic vegetation. They will live in almost any situation, thriving in waters of all degrees of turbidity and contamination. They are very hardy under extremes of temperature, and are easily resuscitated after freezing. Carp shipped from Havana, Ill., to New York City by freight arrive alive provided the gills are kept moist by melting ice. Although of lazy habit, resting much of the time on the bottom, they are wary, and are particularly quick to find a way out of a net, or to jump over it. They are omnivorous feeders, taking principally vegetable matter, but insect larvæ, crustaceans and mollusks, and other small aquatic animals as well. They often pull up the roots of tender aquatic plants while feeding. Cole (1905) found them feeding at all times of day. They apparently seek deeper water in winter, where they remain semi-torpid, taking little or no food.

"Carp spawn in the northern United States in May and June. The eggs are small and exceedingly numerous, 400,000 to 500,000 being a common number in a 4 or 5 pound female. They spawn most frequently during the early hours of the morning. One large female is ordinarily accompanied by four or five males. Five or six hundred eggs are emitted at a time, the oviposition being accompanied by much splashing on the part of both sexes. The eggs are scattered about, according to Cole, adhering to roots and stems and other objects. In moderately warm weather the young hatch, in this latitude, in about twelve days. The young carp reach a length of 4 to 6 inches by the end of the first summer, and attain a weight of about 1 pound in twelve months. By the end of the second summer a weight of about 3 pounds may be reached, this depending upon their nourishment. They first spawn in the spring of their third year. Carp in our waters do not ordinarily reach more than 5 to 10 pounds weight, although occasionally specimens have been taken weighing as much as 30 pounds. In Europe, double the latter weight is said to have been reached in one or two instances.

"The carp lends itself more readily, perhaps, than any other fish to the requirements of artificial culture. The rearing of carp is a very ancient practice, a treatise on the subject by a Chinese dating from the third century. In this country it has practically been discontinued since the species has multiplied on such a vast scale in our natural waters. However, the adaptability of the carp to confinement is still taken advantage of in certain localities, especially in the Great Lake region, in the use of retention ponds, in which large numbers of the summer catch are held over to get the advantage of the winter market.

"Carp bite readily on such baits as worms, liver, paste, and bread crumbs, and in fact will take nearly any except live bait, and they are not lacking in game qualities when hooked. They have long been valued by English anglers, but are not much thought of by the American sportsman of the newer school."

EFFECT ON OTHER FISH.

"Among fishermen and anglers in America the carp has both its partisans and its enemies. However, it is coming more and more to be believed that its good qualities more than overbalance the other side of the account, the most serious of the charges against it appearing to rest on uncertain or gratuitously assumed premises. These charges have been, in brief, that carp roil the water and spoil the breeding and feeding grounds of other fish; that

they eat the spawn of other fish and prevent the nesting of such species as bass and sunfishes; that they spoil the feeding grounds of water birds by eating and rooting up the wild rice and other aquatic plants; and that they are of no value either as a food or a game fish. With regard to the first charge it appears doubtful if the damage is serious in waters already as muddy as those of the Illinois and Mississippi rivers. Carp do not naturally seek out clear and cold waters to defile them, and they would probably in no case be serious competitors of such fish as trout and small-mouthed bass.

"The second charge, if true, is a much more serious one; but few direct observations bearing on this point have been made. The common form of the argument, that 'carp eat spawn, as shown by the simultaneous rapid increase of carp and decrease of fine fish,' is not supported by the statistics of the fisheries of the Illinois River."

TABLE NO. 19—COMPARATIVE STATISTICAL DATA, ILLINOIS FISHERIES, INCLUDING ALL RIVERS AND LAKE MICHIGAN—TOTAL PRODUCTS INCLUDE MUSSEL SHELLS AND TURTLES.

	Year.	Number or pounds.	Value.		Year.	Number or pounds.	Value.
‡Men employed..	1894	*1,653	....	Pike............	1894	26,000	$ 1,600
	1899	*2,341	....		1899	22,500	1,387
	1908	*1,359	....		1908	14,000	1,100
Equipment......	1894	....	$ 156,000	Sturgeon........	1894	87,000	2,200
	1899	....	188,000		1899	159,000	3,970
	1908	....	553,000		1908	180,000	7,300
Fisheries prod-				Suckers.........	1894	420,000	9,900
ucts...........	1894	11,537,000	333,000		1899	259,000	7,800
	1899	29,668,000	616,000		1908	281,000	6,400
	1908	74,620,000	1,436,000	Sunfishes.......	1894	206,000	5,200
Black bass.......	1894	97,000	8,000		1899	543,000	12,000
	1899	126,000	11,000		1908	1,714,000	31,000
	1908	532,000	57,000	Wall-eyed pike..	1894	77,000	5,100
Buffalo..........	1894	5,817,000	146,000		1899	28,900	1,800
	1899	4,051,000	112,000		1908	14,000	1,500
	1908	3,042,000	117,000	White, yellow			
Carp............	1894	860,000	21,000	and rock bass.	1894	157,000	7,200
	1899	9,896,000	244,000		1899	167,000	5,600
	1908	21,642,000	574,000		1908	13,000	1,100
Catfish..........	1894	1,962,000	82,000	Perch...........	1894	28,500	616
	1899	1,570,000	69,000		1899	20,000	556
	1908	2,044,000	96,000		1908	238,000	12,000
Crappie.........	1894	168,000	7,700	Turtles.........	1894	*99,000	3,200
	1899	356,000	14,400		1899	682,000	14,500
	1908	1,281,000	35,000		1908	511,000	21,100
Sheepshead......	1894	1,113,000	26,000	Mussel shells....	1894	†24	700
	1899	610,000	17,700		1899	†2,500	43,000
	1908	666,000	20,000		1908	†20,000	184,000
Eels.............	1894	44,000	2,700	Illinois River,			
	1899	29,200	1,600	total products.	1894	3,000	162,009
	1908	31,000	1,800		1899	7,000	382,000
Paddlefish	1894	136,000	2,600		1908	23,000	860,000
	1899	195,000	6,200	Lake Michigan			
	1908	402,000	12,000	dist., fisheries			
				product.......	1908	1,176,000	58,000

* Number. † Tons.

‡ In 1908 more than half the fishermen of the State were on the Illinois River (2,500 persons), and nearly two-thirds of the total capital employed in fisheries ($551,000).

In reference to the last paragraph of the above quotation, the statistics of the Federal investigations in the years 1894, 1899 and 1908 are significant. Dr. Forbes has abstracted these figures as shown in Table No. 19. The statistics cover the entire State of Illinois. It will be observed that during this period the total fisheries product increased in the ratio of about 6½ to 1, the carp increased at the rate of about 25 to 1, the black bass 5½ to 1, crappie, paddlefish, sturgeon, sunfish and perch increased at the ratio of from 8 to 1 to 2 to 1; catfish, and white,

yellow and rock bass substantially holding their own, while buffalo fish, sheepshead, eels, pike and suckers decreased. The buffalo, formerly the principal food fish of the river, markedly decreased, the catch of 1908 being only half that of 1894. This was very much more than made up by the increase in carp. Forbes and Richardson are further quoted as follows:

"If these records show anything at all it would seem to be that the competition of the carp as spawn-eater and water-soiler has not seriously affected many of our Illinois River species. It is by no means improbable that causes entirely apart from depredations and competition of carp may have had a large influence in producing the recent decrease of buffalo and drum. Among such causes may be mentioned increased contamination of waters from municipal and industrial sources; the obliteration, by drainage and diking, of backwaters used as spawning grounds; and the increased rapidity of runoff from the prairie and upland, as a result of tiling and the cutting of the forests, affecting the extent and duration of the spawning havens afforded by both swampy areas and small streams. To these causes is to be assigned the decrease and approximate disappearance of such minor species as pickerel and lake sturgeon, which were never very abundant in the rivers in question, and which began to fall off in numbers long before the carp entered the field.

"It is not denied that carp will eat fish spawn; but it has not yet been shown that they seek out spawn for the purpose of consuming it. Black bass, crappie, and sunfish are doubtless able to defend their nests against carp in any case. Certainly the devouring of spawn has not affected the multiplication, as shown by the output, of any of these three species, or of suckers or catfishes. That even a favorable effect of the multiplication of the carp is not impossible is evident when it is remembered that the myriads of young carp offer an almost inexhaustible supply of food to the growing bass, crappies and sunfish. The drum and buffalo, which have decreased, are in their food habits more directly in competition with the carp, being chiefly bottom feeders, utilizing mollusks, crustaceans, and insect larvæ.

"Of the third charge little can be said. While it is admitted by all competent to judge that carp do uproot vegetation in large quantities, no means are at hand for comparing the effect of this destruction on the decrease of water birds with the effects of the operations of the hunters themselves. Since 1900 the problem has been complicated in the case of the Illinois River by the effect of the increased flow from Lake Michigan, which has diminished vegetation in many areas."

In further reference to the decrease of certain species, Dr. Forbes is further quoted as follows:*

"The cause of this notable decrease in several of our most important native fishes I am strongly disposed to find in excessive fishing due to the enormous multiplication of carp, which is now more important as a fisherman's fish than all the other fishes of the stream put together. This has necessarily stimulated fishing operations until they have become too active for many of our common native species. If we want to keep these valuable fishes up to the normal standard, we must evidently take special measures to that end. Indeed, we have found some remarkable evidence of overfishing at certain local points, especially in Meredosia Bay. This has been seined so steadily and generally that fish resorting there have been pretty well cleared out, and the animal life of the bottom, upon which fish depend largely for their food, has also been very largely destroyed.

"Another cause of the failure of many of our native fishes is believed by my field assistants to be a lack of practicable fish-ways in the dams at La Grange and Kampsville. As our fishes migrate as a rule upstream for their breeding operations and downstream as the water falls in summer, any barrier to their upstream movement necessarily diminishes the stock above it. These lower Illinois dams are under the control of the War Department,

* Unpublished notes on conference between the Illinois State Game and Fish Conservation Commission and the Director of the Natural History Survey, Urbana, Ill., November 11, 1913.

over which your commission has, of course, no control. On the other hand, if the essential facts are authoritatively obtained and laid before that department, the trouble will no doubt be looked after promptly. However, the problem of a satisfactory fish-way has not yet been finally solved. It is now under investigation by the Bureau of Fisheries, and the U. S. Commissioner tells me that he is sending a man to Europe to study the latest developments there, where some improved fish-ways are said to be in very successful use."

CONTAMINATION AND FISH FOOD.

Reference has previously been made to the contamination in the Upper Illinois River through the sewage of the city of Chicago and its double effect; first, its effect in increasing the available fish food, and second, its effect in making the upper waters of the river uninhabitable for fishes. Fortunately the last named effect has not yet seriously invaded the best fishing grounds of the stream. Dr. Forbes treats these effects together in the notes last above referred to, as follows:

"We have noticed in all our upper river work that, where the stream is heavily polluted, this does not have the effect to kill the fishes which belong there. Indeed, I believe we have never seen a dead fish in the Illinois River, evidently killed by foul water. On the contrary, this merely creates conditions which fishes are intelligent enough to avoid. Fishes brought into the sanitary canal by the inflow from Lake Michigan, and thus subjected to the action of the sewage where they cannot escape from it, practically all perish before they reach the Illinois River; but in that stream itself fishes offended by the pollution of the waters simply withdraw into streams, sloughs, and lakes connected with the main river until this becomes tolerable to them again. The assistant in charge of my Illinois River operations, Mr. R. E. Richardson, tells me that he has often seen carp in Mazon slough, near Morris, come down in the morning in large numbers to the mouth of the slough, and line up there at the edge of the river as if anxious to enter it but afraid to do so. Once in a while a fish ventured out a foot or two into the polluted current, but immediately returned. In the normal movements of our river fishes upstream during the breeding season, they simply stop short or turn back upon their course, when they come to unwholesome water in the main river. Similarly, when they find themselves shut out from their usual breeding grounds by drainage operations, they evidently continue their journey until they reach satisfactory locations.

"It is thus that we may explain the evident concentration of fish population of the river in the central part of its course—a section of the stream which, with its overflow lands, is able to maintain, at least for a time, a much larger population than would otherwise have been possible, by reason of the more extensive overflow, the larger size of the lakes, and the longer continuance of high-water stages since the opening of the drainage canal.

"We have found, by a careful comparison of the product of these waters (Thompson Lake) in the minute plant and animal life called the plankton, that the river at that point contains about two and a half times as much plankton per cubic yard of water now as it did before the drainage canal was opened. In other words, we have a very large increase in the amount of the water and a great increase also in the amount of plankton produced. As this plankton product is an index of the quantity of fish food produced in the stream, these facts, as you will see, have a direct bearing on the statement just made with regard to the continued productivity of the river as a whole and the increased product of its central section.

"There is another factor which we must take into account. The Chicago sewage comes into the river at its upper end in a raw state—not available, that is, as a food for fishes. It is rapidly decomposed in the upper part of the stream in midsummer, and in its decomposition it takes the oxygen out of the water, but becomes itself converted into what we call nitrites, and then into nitrates, in which latter stage it becomes available food for plants and indirectly food for animals, and these in turn are food for our river

fishes. This process of the conversion of raw sewage into available food is a gradual one, progressing downstream at various rates according to the stage of water and the temperature at the time; but I have a good deal of reason to suppose that by the time the water has reached the central section this conversion process is practically complete, and that here, consequently, this added food becomes generally available for the sustenance of fishes. I am undertaking right now to test the correctness of this supposition by collecting several series of water samples from selected points the whole length of the river at different stages of water and at different seasons of the year, to be analyzed at the University by the assistants of the Water Survey of the State, which cooperates with me on these chemical inquiries. I have indeed already a large lot of samples of the bottom sediment or slime of the river and the adjacent lakes, in form for chemical analysis; and by next spring I shall be prepared to give you much more definite information upon these points. If I am right in this matter, the central section of the river and the waters connected with it may be regarded as a huge stomach in which the organic matter contained in the Chicago sewage is digested, assimilated, and worked up, in considerable measure, into the flesh of fishes for our consumption."

Although one year's study has indicated a large increase in the plankton of the river, it is not to be inferred that the fish food has increased in the same ratio, for the plankton is a minor element in the food of fishes, most of which feed upon or near the bottom and very few of which use the plankton beyond their youngest stages.

The organic nitrates which are the basis of the plant and animal life of the stream, have apparently not increased per unit of water, but it is fair to state that in bulk the quantity of nitrates is much greater on account of the greater flow of the stream.

It would seem that the inference that a larger bulk of fish food is now available is a fair one.

EFFECT OF INCREASED WATER LEVELS.

The increased water levels that have prevailed in the Illinois River since 1900 have obviously tended to greater water areas and greater areas of land submerged during the breeding season of the fishes.

Prior to 1904 very little had been done in the reclamation of farm lands, but thereafter the reclamation was rapid as has been previously outlined in the part of this report discussing agriculture, and more particularly, the diagrams Fig. 11 to Fig. 19 illustrative of the acres submerged at various water stages.

COMBINED EFFECT OF INCREASED WATER LEVELS AND RECLAMATION.

Fig. 26 indicates: first, the yield of fish from the Illinois River, based on tabular data previously herein presented; second, the greatest water acreage that has prevailed in each of the past years, 1894 to 1915, and third, the water acreage that was equaled or exceeded for about half the time in each of the several years enumerated.

The curves of acreage take into account the reduction in the flooded land occasioned by the levees constructed principally subsequent to 1904.

It will be noted that the yield of fish has fairly well kept pace with the prevailing water acreage. Throughout most of the period considered, the yield has been approximately 100 lbs. of fish per acre of

water surface, prevailing for about half the year. Since 1910, the yield per acre has apparently been smaller, but the data of fish yield for the years since 1908, is perhaps too uncertain to warrant the conclusion that

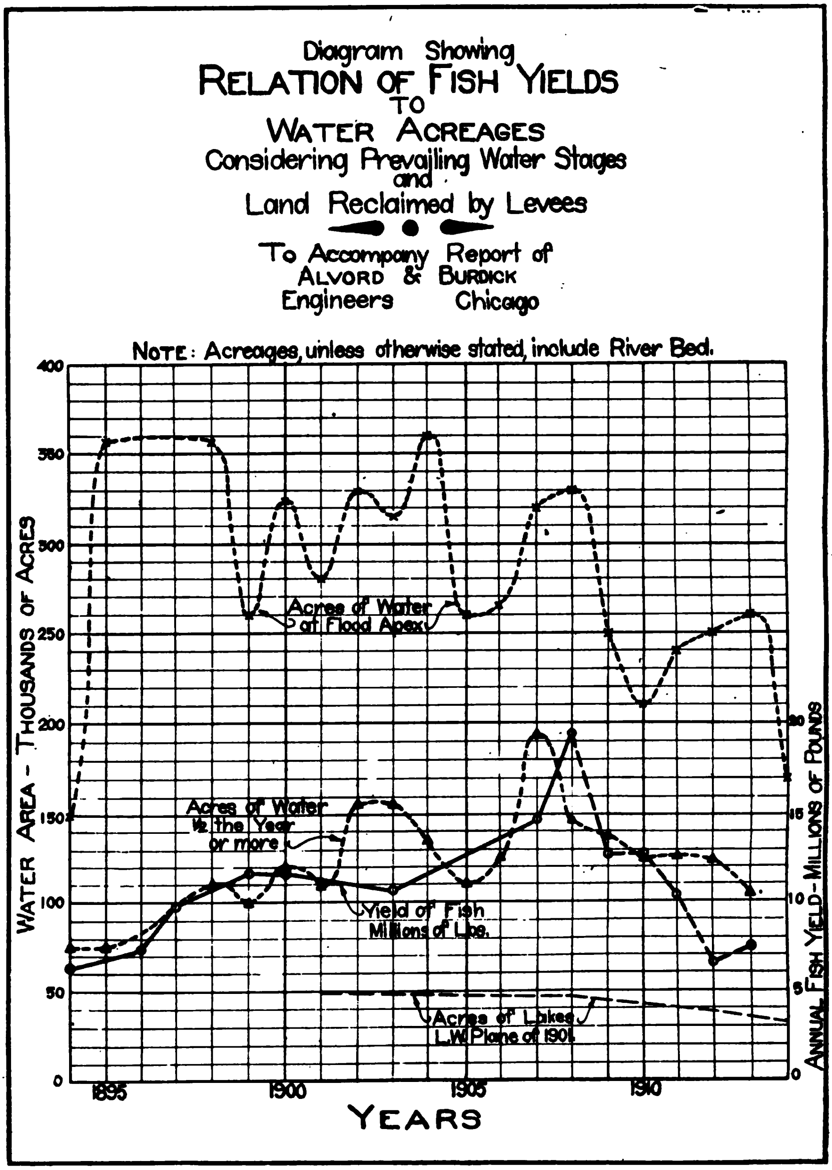


FIGURE 26.

the yield of fish has fallen off more rapidly than the reduction in acreage, although the data tends to point toward this conclusion. At the bottom of the diagram we show the area of lakes at the low water plane

of 1901, platted from Table No. 20 herewith submitted. It seems to us questionable whether valuable deductions can be drawn from the comparison of the fish yields with the low water area of the lakes, especially the low water areas at a fixed datum plane such as 1901. The area in lakes at this plane has always been substantially constant prior to about 1904. There was a slight decrease in the lake acreage between 1904 and 1908, and a more rapid decrease between 1908 and the present time.

TABLE NO. 20—TABLE SHOWING ACREAGE IN LAKES—ILLINOIS RIVER VALLEY BEFORE THE CONSTRUCTION OF LEVEES AND THE ACREAGE AS REDUCED IN SUBSEQUENT YEARS THROUGH CONSTRUCTION OF LEVEE DISTRICTS.

All areas based on the low water plane of 1901.

Description of reach.	Miles of river.	As existing in the— Virgin valley before levee construction—acres.	Year 1904—acres.	Year 1908—acres.	Year 1913—acres.	In 1914, including projects being built—acres.	When all projected districts are built—acres.
Grafton to Kampsville Lock.	31.5	2,710	2,710	2,710	2,150	2,170	2,170
Kampsville Lock to Meredosia	39.8	7,720	7,700	5,950	2,450	1,360	930
Meredosia to Browning	26.0	5,770	5,520	5,180	3,880	2,060	2,060
Browning to Mossville	75.6	24,220	24,220	24,180	20,280	18,130	14,130
Mossville to Henry Lock	24.1	1,870	1,870	1,870	1,870	1,740	1,150
Henry Lock to La Salle	27.4	7,050	7,050	7,050	6,140	6,140	2,440
Grafton to La Salle	224.4	49,340	49,070	46,940	36,770	31,600	22,880

When the present levee projects are completed, the "leveed-in lake areas" will aggregate 40 per cent of the acreage originally existing. When all projected districts are built, about 55 per cent of the lakes will be cut off from the river. In view of the fact that the fishes breed, to a large extent feed, and are taken by the fishermen mainly in the lakes or from overflowed marshes, it does not require a lengthy argument to show that levee construction is detrimental to the public fishery.

FISH YIELD BY DISTRICTS.

Table No. 21 shows the yield of fish in pounds for the various portions of the Illinois River. This data is taken from the statistics of the Illinois Fishermen's Association and the Illinois Fish Commission, which distributes the fish according to the shipping points. The information, therefore, serves to show approximately what parts of the river have produced various quantities of fish under the changed circumstances of recent years.

An examination of this table in connection with Table No. 20 which shows the water acreages divided into the same reaches as covered by the table of fish production, indicates that in the lower portion of the river where the land reclamation has been most extensive, the growth in the fish production between 1896 and 1908 was smallest, and that the largest growths in yields occurred in the middle portion of the river where few levees had been built up to 1908.

TABLE NO. 21—STATEMENT OF FISH SHIPPED FROM THE ILLINOIS RIVER FOR THE YEARS 1896, 1897, 1899, 1900, 1907, 1908.

Name of shipping point.	Miles above Grafton.	1896 From the report of the Illinois Fishermen's Association—pounds.	1897 From the report of the Illinois Fishermen's Association—pounds.	1899 From the report of the Illinois Fishermen's Association—pounds.	1900 From the report of the Illinois Fishermen's Association—pounds.	1907 From the report of the Illinois Fish Commission—pounds.	1908 From the report of the Illinois Fish Commission—pounds.
Grafton	0.0	196,300	186,500	199,900	262,100	322,000	360,000
Hardin	21.2	61,400	67,500	214,000	163,210	50,000	120,000
Kampsville	32.0	240,050	223,050	381,250	595,420	375,000	425,000
		497,750	477,050	795,150	1,020,730	747,000	905,000
Columbiana	32.0	....	....	....	37,600	....	....
Pearl	41.9	190,000	190,000	247,400	397,000	280,000	325,000
Montezuma	50.2	....	....	....	93,050	....	....
Florence	55.6	....	....	....	296,100	....	....
Harris Landing	56.1	....	....	....	172,500	....	....
Blue Island	58.1	....	....	....	15,000	....	....
Valley City	61.6	....	138,000	176,600	179,500	40,000	62,000
Naples	65.6	....	....	222,550	363,500	17,000	22,000
		190,000	328,000	646,550	1,554,250	337,000	409,000
Meredosia	71.3	277,000	171,000	310,500	581,990	500,000	684,000
Beardstown	88.7	1,678,280	1,436,600	1,789,600	1,385,470	1,800,000	1,950,000
		1,955,280	1,607,600	2,100,100	1,967,460	2,300,000	2,634,000
Browning	97.3	520,500	1,103,700	869,700	862,150	1,400,000	1,700,000
Bluff City	105.5	....	153,700	160,100	412,490	....	....
Bath	111.0	270,200	207,500	282,570	368,800	1,500,000	1,900,000
Havana	120.1	1,573,298	1,600,183	1,830,291	1,368,010	2,700,000	3,800,000
Liverpool	128.0	137,515	190,180	210,680	152,930	....	....
Kingston Mines	145.5	11,368	....	....	....	....	....
Pekin	152.9	410,000	200,160	....	773,690	2,800,000	3,400,000
Pekin and Copperas Creek	....	....	....	567,390	....	....	....
Peoria	162.7	931,400	2,124,540	2,104,940	1,240,070	1,500,000	2,800,000
		3,854,281	5,579,963	6,025,671	5,178,140	9,900,000	13,600,000
Chillicothe	180.5	255,500	....	....	765,800	275,000	350,000
Chillicothe and Lacon	....	....	564,650	1,092,700	....	....	....
Lacon	189.1	150,000	....	....	130,500	....	....
Sparland	189.1	....	....	....	....	75,000	102,000
Henry	196.0	245,000	....	....	388,760	700,000	750,000
		650,500	564,650	1,092,700	1,285,060	1,050,000	1,202,000
Putnam	203.0	56,580	....	....	....	120,000	175,000
Henry and Putnam	....	....	938,000	530,000	....	....	....
Hennepin	207.5	28,420	....	....	155,130	....	....
Bureau	210.0	....	....	....	....	42,000	56,000
Hennepin and Bureau Creek	....	....	168,230	166,330	....	....	....
Depue	212.5	....	171,825	162,625	287,000	11,000	19,000
Spring Valley	218.3	....	61,390	88,390	76,410	....	....
La Salle	224.5	....	....	....	....	232,000	270,000
		85,000	1,339,445	947,345	518,540	405,000	520,000
Total weight—pounds	....	7,232,811	9,896,708	11,607,516	11,524,180	14,739,000	19,270,000
Total value	....	$207,687.22	$279,482.07	$362,246.77	$388,876.40	....	....
Price per pound	....	$0.029	$0.027	$0.031	$0.034	....	....

THE POSSIBILITIES OF FISH CULTURE COMPARED WITH ILLINOIS RIVER YIELDS.

To fairly measure the fish productivity of the Illinois River and to gain an approximation of future possibilities, it will be useful to compare the yield of our stream with the fish yields in some foreign coun-

tries where fish culture has been studied and practiced. Most of the available experience has been gained in Germany and Austria, although fish culture has been extensively practiced in Japan and in China for centuries.

ILLINOIS RIVER YIELD, 1908.

In order that we may have a yardstick to measure the foreign experience, it will be useful to set down the Illinois River yield as per U. S. Census for the year 1908. Table No. 22 shows the figures for 1908 in total and per acre of water surface under various conditions, from the low water of 1901 to the high water of 1904. It will be well to keep in mind that 1908 was a banner fishing year, the total product being more than twice the average of the ten or fifteen preceding years. The cause was probably the long continued high water of that spring and several springs preceding during the breeding time and the most important feeding time of the fishes, coupled with the low water in the fall, which gave the fishermen an extraordinary chance to harvest their crop.

TABLE NO. 22—YIELD OF ILLINOIS RIVER FISHERIES (EXCLUSIVE OF MUSSEL SHELLS AND PEARLS) YEAR 1908.

	Pounds.	Value to fishermen at three cents per pound.
Total (by United States Census)	23,896,000	$721,000 00
Per mile of river (La Salle to Grafton—224)	106,700	3,220 00
Per acre of river lakes and ponds, at plane of low water of 1901, excluding lakes within agricultural levee districts (75,430 A.)	317	9 58
Per acre of lakes and ponds at plane of low water of 1901, excluding lakes within agricultural levee districts (46,940 A.)	510	15 40
Per acre of water normally prevailing about one-half the year in river ponds and lakes (i. e. 10 feet on Beardstown gage) based on the virgin river valley as with no levees (157,000 A.)	152	4 60
Per acre of water normally prevailing about one-half the year in river ponds and lakes (i. e. 10 feet on Beardstown gage) excluding area of river (128,510 A.)	186	5 61
Per acre of flood water, 1904, flood plane (358,740)	67.5	2 01
Per acre of land and lakes flooded, 1904, flood plane (280,910)	85	2 57

It is further significant to note that in the natural river and its connected waters, the acreage varies widely with the stage of water, and hence with the season of the year so that it is unfair to fish farming to compare low water acreages in the rivers and lakes with the product of artificial ponds where the acreage is constant, for in the river and connected waters, the wild fish breed and feed over areas tremendously larger than prevail at low water. To base the acre yield of fish on the low water area of the Illinois River is like basing the live stock yield on the farm upon the area of the barnyard. The true measure of the wild fish yield should be based upon an acreage somewhere between that at low water and flood. For comparison with acre yields in agriculture, the yield of the river must be compared with the acres of land that could be reclaimed and hence, practically the area of land above the low water plane frequently flooded, excluding the channel of the river at low water and possibly some of the lakes.

Table No. 22 shows the Illinois River fish yield for 1908 in pounds and value, together with the yields per acre on various surfaces from low

water to high water. It will be observed that the yield of fish was $2.01 per acre of flood water in the flood of 1904, and $15.40 per acre of lakes and ponds at the low water plane of 1901. It was $2.57 per acre of land and lake beds flooded in 1904, excluding the low water channel of the river.

FOREIGN FISH YIELDS.

Actual figures on foreign fish yields are difficult to secure; little authentic information is published in English. Through the assistance of the State Laboratory of Natural History, a search in the German publications has furnished data which are summarized in Table 23. This table includes a few data of actual yield and a few summarized conclusions of foreign observers believed to be well informed. A column is shown of gross return in fish per acre of pond surface. The last column in the table shows the equivalent yield per acre based on the average price of Illinois fish for 1908, which was about 3 cents per pound. This is about one-fourth or one-fifth of European prices.

TABLE NO. 23—SUMMARIZED DATA ON FISH YIELDS IN FOREIGN COUNTRIES.

	Pounds per acre.	Cents per pound.	Gross yield per acre.	Gross yield per acre three cents pound.
1. A German pond fishery with 202 acres in ponds—artificial feeding. Carefully operated—Fischerei Zeitung, 1907. Product almost entirely carp......	252	14.8	$37 20	$ 7 55
2. E. Walters' estimate of the yield of carp per year in Germany without feeding or manuring from ponds laid dry over winter—Fischerei Zeitung, 1907—				
On poor uncultivated land, bog or otherwise sterile bottom..............................	43.5	*10.1	4 40	1 30
On sour and bad meadow land, alder swamps and mud holes..........................	87	10.1	8 80	2 61
On good meadow land........................	174	10.1	17 60	5 22
On first class ground..............................	348	10.1	35 20	10 44
3. A recorded yield from wild waters, Germany. A pond or lake, 8.83 acres, with hard sandy bottom, depth 9 feet, containing a varied assortment of wild fish—Fischerei Zeitung, 1908..........................	1,517	....	....	45 51
4. Yield of cloister ponds in Jutland, Denmark. Four national ponds; fish not fed. (F. Z., 1910)........	....	....	25 40	....
5. Unusual yield of carp in small pond culture, Japan, heavily fed. 225 acres in very small ponds. Fischerei Zeitung, 1907..............................	1,778	3.5	62 23	53 40
6. Statement as to German yields, Zeitschrift Fur Fischerei, 1897—				
Small fish ponds not unusual................	....	....	30 00 to 40 00	....
If ponds are fed from wastes of farm or an entire community—pounds of carp..........	267 to 334	....	....	8 02 to 10 00
Village of Kraschnitz, 10 acres product in year, 1896..............................	....	....	71 00	†21 30
Known cases by feeding and the use of newer rational methods..........................	....	....	100 00	†30 00

* Average price for carp in Germany, 1907.
† Assuming German price to have been 10 cents per pound.

Although some remarkable yields are shown up to $100.00 per acre per year at foreign prices, the German experience, which seems to be more conservative and accurate, seems to give promise of not more than from $35.00 to $40.00 per acre at the German prices, and from $7.00 to $10.00 at the American prices now prevailing. The greatest fishing year on the Illinois River seems to compare quite favorably with these figures.

THE YIELD OF A FISH FARM.

As bearing upon the future possibilities in the Illinois River valley, it is instructive to quote the somewhat detailed figures of one commercial fish farm in Germany as shown in Table No. 24. It will be observed that 202 acres of water surface divided into 52 ponds, with a total investment of $29,094, including land, returned gross $37.30 per acre at an annual cost including four per cent on the investment of $27.15 per acre, leaving a net profit of $10.15 per acre. The net return on the investment exclusive of interest was 11 per cent.

It is instructive to note that the overseer received only $432 per year and that the total expense for labor was only $1,140; further, that the average price received for fish was about 13.6 cents per pound. At present American prices for labor and for fish, the yield from this farm would have been very much less than the running expenses. Where suitable ponds exist, however, or can be cheaply constructed on land not otherwise useful, as is the case in many of the levee districts of the Illinois River Valley, it is possible that intelligent fish culture as an adjunct to farming can be made practicable. It is understood that experiments along this line are now being made by farmers in the valley. It would be well if their efforts in this direction could be so supervised by the State that the experiment is fairly tried.

TABLE NO. 24—FINANCIAL STATEMENT OF A GERMAN POND FISHERY FROM THE FISCHEREI ZEITUNG, 1907, P. 517.

Area of water surface 202 acres divided into 52 ponds.

Value of Plant—	
Land	$11,527 20
Pond system	8,902 80
Buildings	2,808 00
Fish	4,126 80
Old inventories	343 20
Gates and sluices	1,386 00
Total	$29,094 00

	Total.			Per acre.	
Income from sale of fish (principally carp at 13.6 cents per pound)*			$7,535 04		$37 30
Expense and Fixed Charges—					
Four per cent on $29,094	$1,163 76				
Land and building tax	53 04				
Fire insurance	3 84				
		$1,220 64		$ 6 05	
Repairs to buildings	$ 76 08				
Renewal of implements	72 00				
Renewal of gates and sluices	92 40				
Salary of overseer	432 00				
Other help	708 00				
Transportation charges	204 00				
Fertilizers	172 80				
Lime	124 08				
Fish food	1,788 00				
Office expense	151 20				
Sickness and medicines	13 20				
Loss of fishes	433 92				
		4,267 68		21 10	
Total			$5,488 32		$27 15
Net profit			$2,046 72		$10 15

* The sales of fish in normal years from this property averages as follows:

Carp, pounds	47,178
Tench, pounds	2,866
Trout, pounds	875
Total, pounds	50,919

PART VI.

PAST FLOODS AND THE PROBABILITIES OF THE FUTURE.

From what has been said in Part III, as to the extent to which the construction of levees has encroached upon the bottom lands, it will be realized that the safety of these and other bottom land improvements depends upon the adequacy of the designs to meet the future flood conditions. Waterways must be maintained of sufficient width and depth to permit the passage of the floods.

In the consideration of this matter, it becomes necessary to estimate the maximum rates of flow likely to occur, for a comparison of flood heights alone, past and future, is impracticable on account of the important changes brought about through levee construction.

In making an estimate of future flood rates, it will be necessary to closely examine past experience, for we can view the future no more accurately than we can see the past. The past furnishes the best guide for the future. It, therefore, becomes of significance to inquire as to the flood rates that have occurred upon the Illinois River. In this inquiry it will be useful to examine a record of flood heights, for, while the greatest height and greatest flow are not always simultaneous, they are likely to be approximately so, and we may reasonably look for the greatest flow rates among the years when the highest gage readings occurred.

FLOOD HEIGHTS.

Table No. 25 shows the maximum gage height in each year so far as it is a matter of record; at Peoria from 1867 to 1914, and at Beardstown, Pearl and Grafton since 1879 or 1880. These are not simultaneous gage readings, but record the highest elevation of the water during the year at the several places. The date of each high water is noted in the table. It will be observed that the same flood does not always produce the highest water of the year at every place upon the river; thus, very frequently the maximum gage height at Grafton occurs in May, June or July, being influenced principally by the Mississippi River. Pearl is influenced by the Mississippi River to a less degree. At Beardstown and Peoria the gage heights are governed almost entirely by Illinois River flows, the maximum flood usually occurring in March or in April.

The flood of greatest height upon the Illinois River occurred before the establishment of the present gages. This flood was so remarkable however, as to leave well authenticated marks well distributed throughout the river valley and for comparative purposes, we have shown the gage height of this flood at the four places noted, as it would have been had gages been in place as at present.

TABLE NO. 25—HIGHEST WATER IN EACH YEAR—GAGE HEIGHT AT SALIENT PLACES ON ILLINOIS RIVER.

	Peoria.		Beardstown.		Pearl.		Grafton.	
Miles from mouth	163.0		88.9		43.1			
Zero of gage Memphis D.	435.82		427.25		419.70		410.96	
Low water of 1901	5.5	July 26–28	6.7	July 26–28	5.42		1.4	Dec. 17–18
1867	21.33	Feb. 20						
1868	15.75	May 12						
1869	19.17	July 1						
1870	16.25	Mar. 29						
1871	15.66	Mar. 19						
1872								
1873	15.42	Apr. 13						
1874	13.75	Feb. 19						
1875								
1876	16.58	Apr. 7						
1877	15.50	Apr. 5						
1878								
1879			11.7	Apr. 22	8.6	Apr. 25		
1880			13.4	May 17	16.6	May 1	19.05	July 8–9
1881			16.1	Dec. 31			22.89	May 5
1882			17.8	June 16			23.14	July 5–6
1883	20.88		21.8	Feb. 25			23.34	June 25
1884	17.66	Mar. 29	16.6	Apr. 2			21.09	Apr. 6–7
1885					16.58	Jan. 22	17.28	Apr. 29
1886	16.00	Feb. 19	16.0	Feb. 26	14.08	Feb. 27	18.47	May 15
1887	18.66	Feb. 19	16.5	Feb. 23	14.75	Feb. 28	13.65	Feb. 16
1888	14.10	Mar. 30	13.5	Apr. 3	11.08	Mar. 29	22.40	May 30
1889			12.0	June 27	9.17	July 2	14.39	May 31
1890	13.30	June 25	13.5	Jan. 20	9.83	Jan. 19	14.64	June 30
1891	15.00	Apr. 17	12.8	Apr. 24	10.70	Apr. 26	14.9	Apr. 26
1892	21.90	May 9	18.4	May 15	20.42	May 19	25.69	May 18
1893	19.90	Mar. 15	17.0	Mar. 14	18.10	May 5		
1894	12.30	Mar. 14	9.8	Mar. 20	7.75	Mar. 22	14.4	May 12
1895	15.00	Dec. 31					14.4	Dec. 22
1896	14.70	Jan. 1					18.1	May 30
1897	18.30	Mar. 24			18.33	Apr. 7	23.2	May 2
1898	19.30	Mar. 31	19.9	Apr. 1	18.33	Apr. 6	18.0	May 23
1899	15.10	Mar. 22	14.1	Mar. 14	12.50	Mar. 22	18.2	May 25
1900	19.90	Mar. 16	17.7	Mar. 19	16.08	Mar. 22	17.2	Mar. 16
1901	17.70	Mar. 31	15.2	Apr. 6	14.00	Apr. 10	16.6	Apr. 10–11
1902	21.00	July 22	18.0	July 26	17.30	July 28	20.4	July 26
1903	19.30	Mar. 12	17.0	Mar. 15	20.60	June 12	28.65	June 11
1904	23.00	Mar. 28	20.0	Apr. 4	19.30	Apr. 7	24.07	Apr. 30
1905	17.90	May 19	14.1	June 14	13.00	June 17	18.3	June 16
1906	15.90	Mar. 7	15.6	Apr. 10	15.20	Apr. 13	18.3	Apr. 15
1907	20.40	Jan. 24	18.3	Jan. 29	16.10	Feb. 3	17.9	July 25
1908	22.20	Mar. 10	20.6	May 24	19.70	May 26	23.8	June 18
1909	17.80	May 5	15.5	May 10	15.50	May 12	22.6	July 15
1910	17.30	Mar. 12	14.8	Jan. 31	12.80	Jan. 27	14.3	May 10
1911	15.80	Nov. 24	16.9	Oct. 7	15.10	Oct. 7	15.4	Oct. 4
1912	19.80	Apr. 1	18.8	Apr. 4	19.60	Apr. 10	23.6	Apr. 10
1913	22.30	Mar. 30	21.8	Apr. 5	20.80	Apr. 11	20.5	Apr. 11–12
1914	15.40	Apr. 8	13.4	Apr. 15	10.20	Apr. 16	12.6	June 27
1844	26.92		22.50		26.50		32.16	

It will be noted that this flood is nearly four feet higher than any other flood recorded at Peoria, .7 of a foot higher at Beardstown, 5.7 foot higher at Pearl, and 6.5 foot higher than any other flood recorded at Grafton. It is worthy of note that the 1913 flood at Beardstown closely approached the 1844 flood in height, but was considerably less in height at the other places given in the table. This matter is considered elsewhere in this report.

The eight highest floods at Peoria (Lower Wagon Bridge) were as follows:

Year.	Gage height.	Year.	Gage height.	Year.	Gage height.
1904	23.0	1892	21.9	1883	20.88
1913	22.3	1867	21.33	1907	20.4
1908	22.2	1902	21.0		

These are the only floods exceeding 20 feet on the gage.

FLOOD OF 1904.

The flood of 1904 which attained the greatest height at Peoria reached since 1844, was measured at numerous places upon the river by the U. S. Engineers in connection with their report on the waterway, and also by the U. S. Geological Survey in connection with the hydrographic work on the rivers of the United States. Measurements were made at the apex of the flood as nearly as possible, and also at numerous other gage heights between flood stage and low water, particularly in the year 1904, but also in the years 1903, 1905 and 1906. Reference has previously been made to measurements by Mr. Jacob A. Harmon in 1900 and 1899.

TABLE NO. 26—GREATEST MEASURED FLOWS—FLOOD OF 1904.

Illinois River.

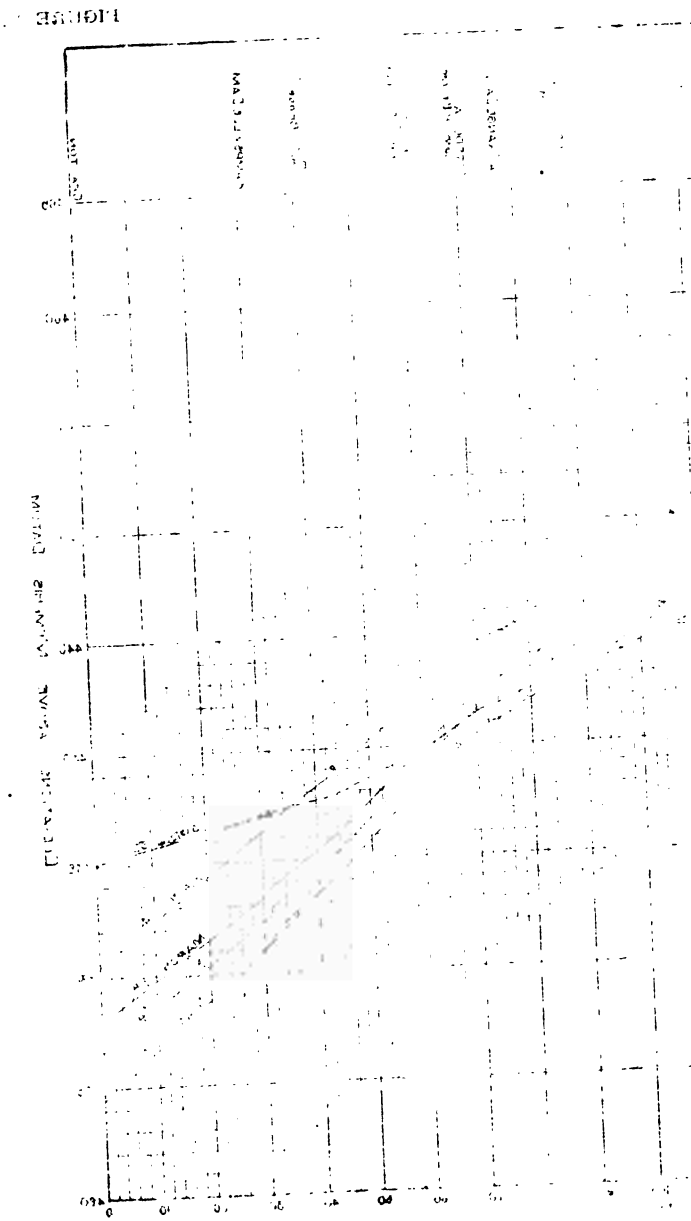
Location of discharge section.	Miles from Grafton.	Date of measurement.	Gage height—feet.	Greatest measured flows—sec.-ft.	By whom measurement was made.	Remarks.
Pearl—C. & A. bridge	43.2	Apr. 5	19.3	115,204	U. S. Engrs.	.08′ below crest on April 6.
Pearl—C. & A. bridge	43.2	Apr. 9	19.1	109,404	..do	.28′ below crest on April 6.
Beardstown—city bridge	88.8	Mar. 31	19.4	90,647	..do	.6′ below crest on April 4.
Beardstown—city bridge	88.8	Mar. 29	18.5	88,924	..do	1.5′ below crest on April 4.
Havana—city bridge	119.9	Apr. 1	19.9	80,302	U. S. G. S.	Crest on April 1, 42,000 c. f. s. estimated over road.
Havana—city bridge	119.9	Mar. 29	19.7	76,071	..do	.2′ below crest, 9,000 c. f. s. estimated over road.
Havana—city bridge	119.9	Mar. 28	19.4	74,314	..do	.5′ below crest.
Havana—city bridge	119.9	Mar. 26	18.1	75,970	U. S. Engrs.	1.8′ below crest.
Havana—city bridge	119.9	Mar. 25	17.6	74,268	..do	2.3′ below crest.
Peoria—P. & P. U. bridge	160.7	Mar. 28	21.83	58,370	U. S. G. S.	Crest on March 28.
Peoria—P. & P. U. bridge	160.7	Mar. 31	21.48	44,808	..do	.35′ below crest.
Peoria—P. & P. U. bridge	160.7	Apr. 2	21.17	41,934	..do	.66′ below crest.
Peoria—P. & P. U. bridge	160.7	Apr. 7	20.12	51,558	..do	1.71′ below crest.
Peoria—P. & P. U. bridge	160.7	Apr. 9	19.66	52,367	..do	2.17′ below crest.
Peoria—P. & P. U. bridge	160.7	Mar. 23	19.3	59,333	U. S. Engrs.	2.53′ below crest.
Peoria—P. & P. U. bridge	160.7	Mar. 22	18.8	57,538	..do	3.03′ below crest.
Ottawa—C. B. & Q. bridge	239.6	Apr. 2	—117.3	54,473	U. S. G. S.	1.9′ below crest on Mar. 27.
Ottawa—C. B. & Q. bridge	239.6	Mar. 30	—118.3	46,561	..do	2.9′ below crest on Mar. 27.
Devine—E. J. & E. bridge	270.7	Mar. 26	—78.47	57,097	U. S. G. S.	Crest on March 26.
Devine—E. J. & E. bridge	270.7	Mar. 27	—79.98	50,920	..do	1.51′ below crest.
*Mouth of Jackson Creek	278.4	Mar. 25	—74.1	20,078	U. S. G. S.	.11′ below crest on Mar. 26.
*Mouth of Jackson Creek	278.4	Mar. 25	—74.6	17,943	..do	.6′ below crest on Mar. 26.
*Mouth of Jackson Creek	278.4	Mar. 25	—74.8	17,343	..do	.8′ below crest on Mar. 26.

* Flow of Des Plaines River near its mouth.

Table No. 26 shows a summary of the flow measurements made by the U. S. Engineers and the U. S. Geological Survey, at and near the apex of the flood of 1904 at several places throughout the length of the river. It will be observed that all measurements were not made exactly at the apex of the flood, and although at most of the places, the measurements agree fairly well, stage of water considered, the measurements of the U. S. Engineers generally give greater flows than those of the U. S. Geological Survey, and at Peoria, the difference is large when the stage of the river is considered at the times of the respective measurements.

CONCLUSIONS OF U. S. ENGINEERS.

As a result of their measurements, the U. S. Board of Engineers reported the maximum flow rates of the 1904 flood as follows:



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	Second-feet.
Joliet, Des Plaines River	22,000
Channahon, Des Plaines River	22,000
Devine, Illinois River	73,000
Ottawa, Illinois River	85,000
Peoria, Illinois River	90,000
Havana, Illinois River	100,000
Beardstown, Illinois River	115,000
Pearl, Illinois River	117,000

PEORIA RATING CURVE.

As Peoria is one of the best measuring points on the river, and a long gage record is available here, it becomes of considerable importance to determine the proper gage height and flow relation as closely as the data will permit.

Turning to Fig. 9 (the diagram of rating curves) it will be observed that six measurements have been made, resulting in flows between 50,000 and 60,000 second-feet at gage heights between 19 and 23 feet, two by the U. S. Engineers, three by the U. S. Geological Survey, and one by Mr. Jacob A. Harmon. The one measurement at the flood apex made by the U. S. Geological Survey is not in accord with the five other measurements which were made at stages from 2 to 4 feet lower.

As bearing upon this matter, Mr. J. W. Woermann, C. E., in his report to the United States Engineer Office, makes the following comment:

"During the flood stage the work was concentrated between Peoria and the mouth for the reason that the U. S. Geological Survey had a party at work taking measurements on the upper part of the river. At Peoria and Havana, measurements were taken by both parties, and it is possible to compare their results. The results agree fairly well for ordinary stages, but at high water our curves give greater discharges than those of the U. S. Geological Survey. In my opinion, this is accounted for by the fact that the observers of the U. S. Geological Survey used small Price current meters with comparatively light weights, and we know from our own observations, that the meters were deflected out of a vertical position very materially. This, of course, resulted in the meters recording a lower velocity than actually existed. It is believed, therefore, that the results obtained on this survey with a large Price current meter and a 60 pound weight are more reliable.

"It should also be stated that our measurements were taken from a cable away from the disturbing influences of the bridge piers, whereas their meters were suspended directly from the bridges in taking observations."

It was thought that the above apparent difference might be explainable by different conditions of river slope, and therefore, Fig. 27 was prepared which shows the profile of the flood surface on various dates from March 23d to April 30th.

The measurement of the U. S. Engineers was made on March 23d, at which time the fall between the Lower Wagon Bridge and Pekin was 3.25 feet. The measurement of the U. S. Geological Survey was made on March 28th, at which time the fall between these places was 3.6 feet. The gage height at Peoria was 2.8 feet higher on March 28th, and at Pekin 2.45 feet higher on March 28th than on March 23d.

These figures indicate that the velocities on March 28th must have been equal to or slightly greater than those on March 23d, and that

therefore, the difference in the flow results cannot be accounted for on the score of changed river conditions. The flows undoubtedly were considerably greater on the 28th than on the 23d.

There is a further reason for believing that the flow on March 28th was considerably larger than would be indicated by the U. S. Geological Survey measurement. At another place in this report the flow coefficients prevailing in the stream and in the river valley are discussed, and tables are shown of the values prevailing in the river prism and in the flooded valley, according to the best available information on this and other rivers. If a flow so small as that reported by the U. S. Geological Survey occurred, the flow coefficients would be materially smaller than evidently obtained elsewhere on the river and upon other rivers. In fact, using reasonable values in the channel section proper under the cross-sections and slopes prevailing, the channel should have been capable of discharging somewhat more water than was measured, without considering any flow at all as traveling by way of the flooded bottom lands.

For all of these reasons, we are inclined to the belief that the maximum flow rate at Peoria was about 80,000 second-feet at the flood apex, or slightly less than the estimate of the U. S. Engineers.

At other places further down the river, the agreement in measurements is fairly close. In the light of all the measurements made, we would place the prevailing flow rates at figures slightly under the estimates of the U. S. Engineers for the middle reaches of the river.

CONCLUSIONS AS TO FLOOD RATES IN 1904.

In order that we may have concrete figures for use hereafter, it seems necessary to determine the 1904 flows. It is our opinion that the figures of flow set down in Table No. 27 are most closely concordant with all the available information. The table also shows the drainage area tributary to each of the observation stations, and the flow rate in cubic feet per second per square mile.

TABLE NO. 27—ESTIMATED MAXIMUM FLOW—FLOOD OF 1904.

Illinois River.

Place.	Date.	Miles above Grafton.	Gage height—feet.	Estimated flow—second-feet.	Drainage area—square miles.	Flow in second-feet per square mile.	Remarks.
Grafton	Apr. 20	......	....	125,000	27,914	4.48	
Pearl	Apr. 6	43.2	19.4	115,000	26,182	4.40	U. S. Engrs. estimate, 117,000.
Beardstown	Apr. 4	88.8	20.0	105,000	23,444	4.47	U. S. Engrs. estimate, 115,000.
Havana	Apr. 1	119.9	19.9	90,000	17,454	5.15	U. S. Engrs. estimate, 100,000.
Peoria	Mar. 23	162.3	21.8	80,000	13,479	5.94	U. S. Engrs. estimate, 90,000.
	Mar. 28	......	23.0	....	....	......	
†Ottawa—C. B. & Q. Bridge	Mar. 27	239.8	—113.35	85,000	10,229	8.31	Estimate of U. S. Engineers.
†Devine—E. J. & E. Bridge	Mar. 25	270.7	—78.8	73,000	6,538	11.21	Estimate of U. S. Engineers.
*Channahon—near mth. of Jackson Creek	Mar. 26	278.0	14.1	22,000	975	22.5	Estimate of U. S. Engineers.
*Joliet—below Econ. Lt. & Power Co. Dam	Mar. 23	288.4	—5.5	22,000	975	22.5	Estimate of U. S. Engineers.

* NOTE.—These places on Des Plaines River above head of Illinois River.
† Sanitary District gages.

FLOOD OF 1844.

The flood of 1844 as before stated, reached greater heights than any previous flood at every place upon the river. In order that some idea might be formed as to the rate prevailing during this flood, some comparisons have been made relative to the comparative cross-sections, slopes and mean depth prevailing in 1844, and in 1904 under the measured flood.

It has been demonstrated that in the flow of rivers, the average velocity and hence the delivery, will vary approximately as the cross-sectional area, the square root of the mean depth and the square root of the slope. This relation holds so long as the retarding effect of the surfaces over which the water passes remains constant.

It is not possible to determine simultaneously gage readings for the flood of 1844. The best that can be done is to reason from the high-water marks which are determined with fair accuracy at numerous places and to compare them with similar highwater marks in the measured flood of 1904.

The high water marks of 1844 are fairly well determined at Peoria and at Pekin, points about ten miles apart. The figures bearing upon this point are as follows:

	Flood of 1904.		Flood of 1844.
Average cross-sectional area, square feet......	79,020		111,220
Mean depth—feet........................	12.2		15.85
Fall Peoria to Pekin—feet................	3.6		1.7
Square root of mean depth................	3.50		3.98
Square root of fall........................	1.90		1.30
Ratio of cross-sections....................		1.40	
Ratio of depth, square roots...............		1.14	
Ratio of fall, square roots.................		.69	
Product of ratios net relation..............		1.10	

These figures so far as they go, would indicate that the 1844 flood was about 10 per cent greater than the flood of 1904 in the vicinity of Peoria.

A similar comparison between LaGrange and Pearl, a distance of 33.2 miles, in which the fall was 2.3 feet in 1844, and 6.38 feet in 1904, indicates that at this place the flood rate of 1844 was about 32 per cent greater than in 1904.

A comparison over a longer stretch of river, namely, from Beardstown to Grafton, upon the same basis, would indicate a quite materially higher ratio than the above, but it is believed that not much reliance can be placed on the extreme highwater slope indications so near to the Mississippi River, the heights at Grafton being very largely governed by agencies outside of the Illinois River.

The above comparisons take no account of the influence of increased depth and velocity, upon the frictional resistance of the water in passage. These factors would tend to increase the apparent flows in 1844 by the amount of about 25 per cent. (Effect of these factors on value of C in Kutter's formula.) The comparison further takes no account of the

difference in skin friction that may have existed (as covered by the value of n in Kutter's formula). This would tend to reduce the comparative flow rates in 1844, for much of the bottom land has been cleared of trees and brush, especially in the lower river in the year of 1904. Computations seem to show that about one-half the flood passed by way of the bottom lands in the lower part of the river in 1904, at which time little had been done in the way of levee construction. This land was probably a jungle in 1844, highly resistant to passage of water.

The river channel proper was probably in much the same condition in 1844 and 1904, and if we disregard the water passing over land, and consider the channel section of the river only, the hydraulic elements would indicate an excess flow rate in 1844 of about 14 per cent in the reach between Peoria and Pekin, and in the reach from La Grange to Pearl, the channel flow rates would be indicated as approximately equal.

The slopes between Pekin and Havana would seem to indicate higher flow rates in 1844 than any of the above, unless it can be shown that the land was wooded to a much greater extent in 1844, and upon this point we have no information. The land at the present time has perhaps the highest percentage of trees and brush of any reach on the river. Between Peoria and the Great Bend, the high flows are also indicated, but the flood marks are not so numerous or well authenticated.

It is believed that there is good reason for the conclusion that in the lower river, say below Beardstown, the flow rate in 1844 at no time was materially greater than the rate observed in 1904. In the upper river, the indication is less clear and the flood rates of 1844 probably exceeded those in 1904 by not less than 15 per cent, and possibly more.

FLOOD OF 1913.

The flood of 1913 produced a maximum flow rate at Peoria about 10 per cent less than the flood of 1904. In the lower river at Beardstown it reached a height within .7 of a foot of the 1844 flood, but it traversed a river differing greatly from that existing in 1904 and previously, particularly between Beardstown and Grafton. The flow cross-section was greatly reduced on account of the levee construction. For reaches of considerable length, the water was confined between agricultural levees and the high bank on the western side of the river, closely approximating the channel conditions in the main stream here and elsewhere.

We have elsewhere herein demonstrated the values for coefficients of flow generally prevailing in the channel sections of the Illinois River, and if these values are applied to the channel sections and slopes prevailing below Beardstown in the flood of 1913, it is indicated that the maximum flow rates during this flood were closely approximate to the measured rates in the flood of 1904. There is reason to believe that in 1913 as in 1904, a large increment was furnished by the Sangamon River, and the rates thus produced were probably accentuated by extensive operations in channel straightening in the Sangamon River bottoms completed prior to 1913, that tended to reduce the natural storage in the valley of the Sangamon River, and somewhat increased the rates of flow delivered to the Illinois at Beardstown.

All these matters seem to indicate that the maximum flood rate in 1913 was about 10 per cent less than the rate in 1904 in the vicinity of

Peoria, and substantially equal to the 1904 flood rates at Beardstown and below.

THE PROBABLE FLOODS OF THE FUTURE.

It becomes necessary, if we may design works that will safely stand the floods hereafter, to estimate as accurately as we can the flood rates that the future is likely to produce. In estimates of this kind we can do no more than to examine the past and to assume that what has occurred before may occur again, and referring particularly to the Illinois River, it will not be sufficient to base our conclusions on the experience of this river on which continuous records cover only about fifty years. Due weight must be given to the experience on other rivers having a longer record, for experience has shown that the peculiar combination of circumstances that produce a deluge and flood materially greater than the ordinary large flood, may occur on any stream at any time, and where records are sufficiently lengthy, it is shown that the intervals between such occurrences may be very great, in fact, so long as centuries, or, the great floods may follow one another closely. The experience in this regard upon some streams of long record is instructive.

GREAT FLOODS.

Upon the Mississippi, the greatest flood since the occupation of the valley occurred in 1844. The flood second in magnitude occurred in 1785. There was an interval of fifty-nine years between these floods and in the seventy-one years since 1844, this flood has not been closely approached.

The flood of 1883 on the Ohio River at Cincinnati was the greatest flood up to that time since the river has been known to the white man. The following year a slightly greater flood occurred which has not since been equaled. At Cairo on the same river, the record flood occurred in 1883. It was slightly exceeded in 1912, and again exceeded in 1913.

The late Mr. Emil Kuichling, C.E., quotes the official investigation into the floods of the river Seine at Paris, and states that in observations covering 400 years, the greatest flood occurred March 1, 1658. The flood second in magnitude occurred January 28, 1910. This flood almost equaled the former great flood and was estimated at 83,500 second-feet on 16,860 square miles, a rate of about 5 second-feet per square mile, which is approximately equal to the flood of 1904 upon the Illinois River. The flood third in magnitude occurred December 26, 1740; it was slightly smaller than the flood last above mentioned.

Mr. Kuichling also quotes the experience on the River Danube at Vienna, on which the highest water from well attested flood marks occurred in the year 1501. The flood was roughly estimated at 503,200 second-feet on 39,200 square miles, a flood rate of about 13 second-feet per square mile. Numerous floods have since occurred upon this river, but none larger than 307,800 second-feet. This is over 25 per cent less than the discharge in the great flood of 1501.

The above citations emphasizes the value of long records and the chance for serious error in the drawing of conclusions from a short record.

FLOOD RATES ON OTHER STREAMS.

As throwing light upon what may occur in the valley of the Illinois River, we have collected such data as we could secure relative to the maximum flood flow rates that have been observed on the streams in and adjacent to the State of Illinois. We show this data in table No. 28. These streams are all much smaller than the Illinois River, and as would be expected, show flood rates per unit of drainage area considerably higher than the rates on the Illinois River. The streams listed include Indiana, Michigan and Wisconsin, and the flow rates vary from 7 to 34 second-feet per square mile.

TABLE NO. 28—MAXIMUM FLOOD FLOWS ON STREAMS IN AND ADJACENT TO ILLINOIS.

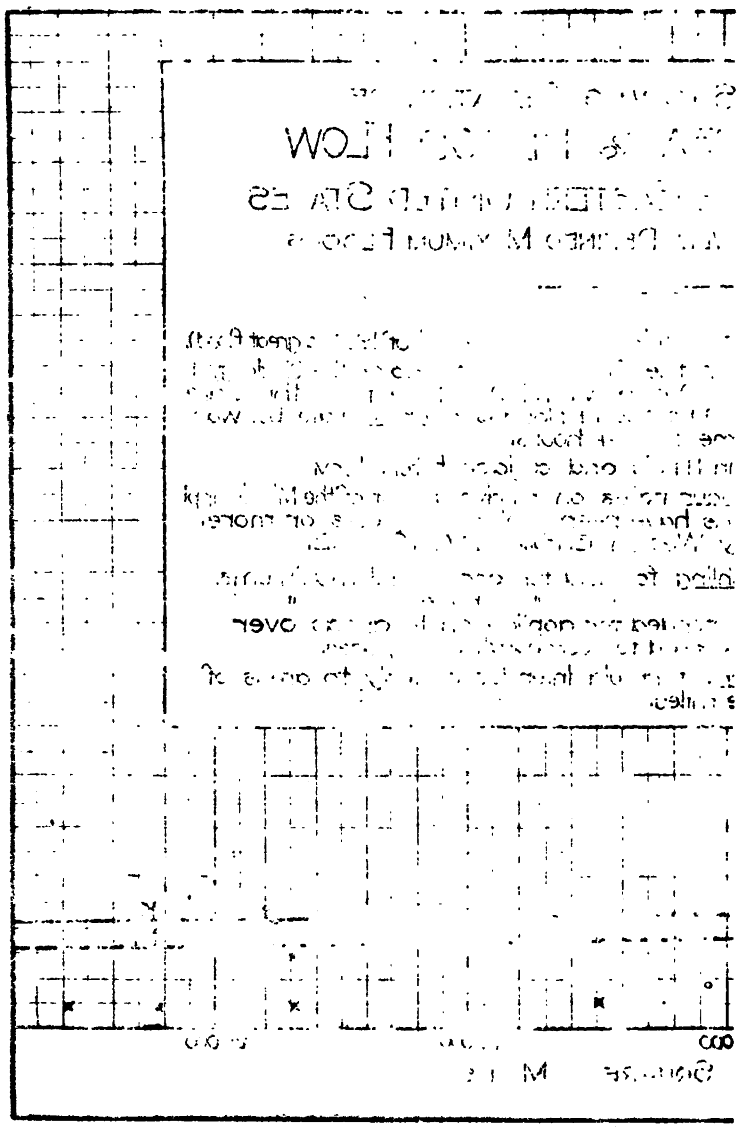
River.	Place of measurement.	Drainage area.	Date.	Flood flow—second-feet.	Flood flow—second-feet. square mile.	Authority.
Des Plaines River	Riverside, Ill.	633	June 1892	13,300	21.0	T. T. Johnston.
Grand River	Grand Rapids, Mich.	4,900	Mar. 27, 1904	39,400	8.04	W. S. No. 147.
Kaskaskia	New Athens, Ill.	5,200	May 1908	54,440	10.45	U. S. G. S. and I. I. C.
Kaskaskia	*Carlyle, Ill.	2,705	May 1908	19,946	7.37	U. S. G. S. and I. I. C.
Kaskaskia	Shelbyville, Ill.	1,040	May 1908	10,580	10.18	U. S. G. S. and I. I. C.
Kaskaskia	Arcola, Ill.	390	May 1908	3,868	9.92	U. S. G. S. and I. I. C.
Wabash River	Logansport, Ind.	3,163	Mar. 27, 1904	56,880	17.98	†W. S. Nos. 147 and 128.
White River	Shoals, Ind.	4,900	Mar. 29, 1904	79,950	16.33	†W. S. Nos. 147 and 128.
Wisconsin	Kilbourn, Wis	8,000			10.0	D. W. Mead.
Grand River	Lansing, Mich.	1,230	March 1904	25,000	20.3	W. S. No. 129.
Huron		757	July 7, 1902	5,510	7.3	L. E. Cooley.
Black	Neillsville, Wis	675		23,060	34.1	U. S. G. S.
Lake Geneva	Lake Geneva, Ill.	19.4		290	15.0	
Calumet	Riverdale	693	Mar. 7, 1908	11,000	15.8	L. K. Sherman.
FLOOD RATES DURING GREAT FLOOD OF 1913, IN OHIO.						
Ottawa River	Lima, Ohio	140	Mar. 13, 1913	12,000	86	W. J. Sherman.
Muskingum River	Marietta, Ohio	7,850	Mar. 13, 1913	250,000	32	W. J. Sherman
Ohio River	do	34,700	Mar. 13, 1913	555,200	16	W. J. Sherman.
Scioto	Columbus, Ohio	1,032	Mar. 25, 1913	80,000	77	Alvord & Burdick.
Olentangy	Columbus, Ohio	520	Mar. 25, 1913	60,000	115	Alvord & Burdick.
Lower Scioto	Columbus, Ohio	1,570	Mar. 25, 1913	140,000	89	Alvord & Burdick.
Wabash	Lafayette, Ind.	7,300	Mar. 13, 1913	136,000	18.6	Rough Est., Sackett.

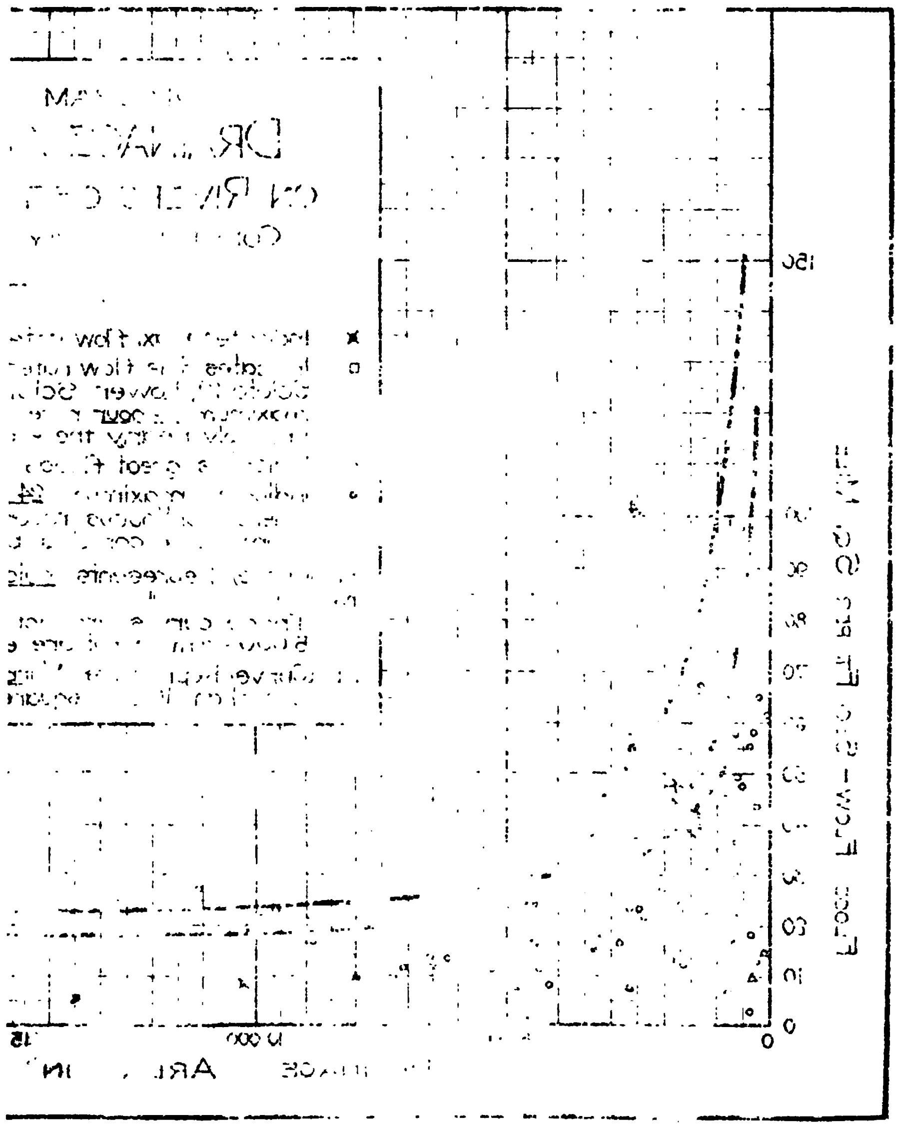
* Estimated that without the storage of the bottom lands, i.e. with the bottoms protected by levees, the unit rate would have been 25 second-feet per square mile. Report of J. A. Harman, Kaskaskia River Improvement.

† Largest flood since 1885 and probably longer.

The same table also shows the flood rates resulting from the greatest rainstorm of record that occurred in Ohio in March, 1913, accomplishing the great devastation at Dayton, Columbus and other Ohio cities. It will be observed that the Ohio River at Marietta, with a drainage area slightly larger than the Illinois, produced a flood rate of 16 second-feet per square mile, nearly three times the maximum recorded rate on the Illinois. It must be remembered however, that the tributary watershed in the western Pennsylvania mountains is a water producer differing greatly from the Illinois prairies. It will be observed that the flow rates on the smaller streams range from 32 to 115 second-feet per square mile.

Fig. 28 shows in diagrammatic form, a composite representation of the data shown upon Table No. 28 also the maximum flow rates upon





a large number of other American streams lying east of the Mississippi, and for purposes of comparison, the greatest recorded flood rates on the Illinois River are shown. It is the purpose of this diagram to illustrate the wide variation in maximum flow rates of the streams of the eastern United States, and to further illustrate the effect of the size of the watershed contributing to the stream flow.

The diagram is platted with drainage area in square miles laid off horizontally, and maximum flood flows in cubic feet per second per square mile, vertically. Each spot represents an observation on some stream, and is platted opposite to the size of its drainage area and its flow rate.

Mr. Emil Kuichling in connection with his report on the New York State Barge Canal, platted similar data for some of these streams and others, and drew curves of relation which are reproduced on Fig. 28 marked "K-2" and "K-1" on the diagram, indicating the flood rates upon drainage areas of various sizes likely to occur rarely, and occasionally, respectively. The Murphy formula for streams of the northeastern United States is also represented by the curve line marked "M." The Kuichling formula was intended to apply to drainage areas not larger than 5,000 square miles, and the Murphy formula to areas up to 10,000 square miles. Curves "M" and "K-1" have, however, been extended to cover the total drainage area of the Illinois River for comparative purposes, and seem to fit conditions fairly well.

It will be observed that 1913 floods on the Ohio streams equaled, or, in one case, materially exceeded the curve of rare floods. It will further be seen that the Illinois River has the lowest flood rates of any of the great rivers recorded, and in its upper reaches where the drainage area is small, it is well below the average of streams having a like drainage area.

ARTIFICIAL CONDITIONS AFFECTING FLOOD RATES.

At the outset it will perhaps be desirable to mention some of the artificial causes that tend to affect flood flows, particularly as these causes have been much discussed of late, and the operation of these causes hereafter might obviously have a tendency to affect conclusions made at this time.

The drainage of low land has affected flood flows in two ways. By draining the swamps which naturally were more or less covered with standing water, these natural flood water storage reservoirs have been destroyed. This would have a tendency to increase flood rates particularly on the adjacent streams. Upon the other hand, the reclamation of swamp land has permitted the soil to act as a receptacle for storage that was not available when the land was flooded with water. This tends to counteract the direct effect of the drainage. The tiling of rolling farm land, an extensive practice in Illinois, has probably had very little effect on floods one way or the other; if anything, the tendency is to reduce the effects of the flood delivered to the streams.

The question of deforestation recently much discussed, is of small concern on the watershed of the Illinois. The majority of the acreage has always been prairie land.

The reclamation of bottom lands on the tributaries of the Illinois, is a more important effect. Considerable work has already been done on the Sangamon in the way of straightening the channel for the purpose of decreasing the frequency of overflow, and in case of flooding, removing the water from the bottom lands more quickly. This practice tends to rob the bottom lands of their ability to store flood waters; to increase the delivery rate of the tributaries, and hence if the practice is extensively pursued, to materially increase the rate at which flood water is delivered in the valley of the Illinois River. As the Illinois River is a great stream, and most of the tributaries are comparatively small, the dangers arising from this work will depend upon the extent to which such reclamation works are built. There are a number of tributaries of the Illinois on which works of this kind are suggested, but the matter has not been sufficiently investigated as yet to form an intelligent opinion as to how extensive these works will ultimately be, and of the effect they may produce upon the flood deliveries of the Illinois River.

So far as the artificial drainage of swamp land is concerned, it is not probable that future operations will be of sufficient moment to materially change the rates that have prevailed in the last twenty years.

NATURAL CONDITIONS AFFECTING FLOOD RATES.

It must not be presumed that conditions are likely to occur that will produce flood rates upon the Illinois River equal to those of the recent Ohio floods. There is no doubt that although the rainstorm producing those floods may occur again, although such a storm never before visited the eastern United States, and may center on the Illinois River watershed, even so, the watershed of this stream could not produce the rates that occurred in Ohio, for the watershed is too large, the stream valleys too wide, and the gradients are too flat. Even so, very much larger floods might be produced, for only the edge of the March, 1913, storm covered the watershed of the Illinois River, and a great flood was produced below Peoria. Had this storm been centered on the Illinois River, there is little doubt but that a record flood would have resulted.

Upon the great rivers such as the Ohio, Mississippi and Missouri, the melting snows have an important effect upon the flood rates, and the greatest floods have resulted through a warm rain on snow, supplemented by torrential rains in the lower reaches of the watersheds affected. The snow conditions on the Ohio and Mississippi are particularly important by reason of the great depth that sometimes covers the ground in Pennsylvania, Wisconsin and Minnesota.

The snowfall is of less importance on the smaller streams, on which the greatest floods usually result from torrential rains, although sometimes supplemented by snow lying on the ground. These smaller drainage areas come within the compass of a much more concentrated rainfall than is possible on the watersheds of the great rivers, on which rainstorm floods are usually produced by a number of storms each covering only a part of the watershed, or the series of recurring storms in a measure following the flood waters down through the drainage area.

The condition of the ground surface has very much to do with the maximum runoff rates, thus, a ground that is already saturated with

a moderate rainfall, is in a condition to deliver a succeeding torrential rain almost entire to the water courses, and more important and of more frequent occurrence, the frozen ground of late winter and early spring produces a similar result. Thus, we almost always have our floods in this latitude in February, March or April. This is true upon the Illinois, except in the lower part of the river where the flood is influenced by the Mississippi and Missouri Rivers which may deliver their flood waters as late as May or June.

Thus, in so far as rainfall and ground surface conditions are concerned, the streams of the central and northeastern United States are much alike, and the principal differences in unit runoff must be looked for in topography. A double effect is here produced, for the flat gradients not only tend to low delivery rates, but also tend to store the flood waters, thus making delivery to the streams over a longer period and at smaller rates.

The effects of topography are much too complicated to give us directly valuable information as to probable flood rates, or even to make definite comparisons between watersheds. An effort has been made however, to accomplish this purpose in another way, namely, by ascertaining the average flood flows of our various streams and comparing the great floods on the streams, each as a ratio of the average flood on the same stream.

COMPARISON BY RATIOS.

This method of comparing flood flow rates was first suggested in a paper by Weston E. Fuller, read before the American Society of Civil Engineers, October 15, 1913. Mr. Fuller has done a great service to the hydraulics of rivers in this suggestion, and in assembling the flood flow data on all our American streams, in such form that intelligent comparison thereof can be made.

Table No. 29 has been prepared largely from his data, but with a few additions, including all the rivers of the United States on which flow records are available, covering ten years or more.

TABLE NO. 29—MAXIMUM (24-HOUR) FLOOD RATES—ALL STREAMS OF UNITED STATES HAVING RECORD OF TEN YEARS OR MORE.

(Compiled from paper on Flood Flows by Weston E. Fuller, M. Am. Soc. C. E.)

Stream.	Place measured.	Drainage area—square miles.	Length of record—years.	Average yearly flood flow—second-feet.	Maximum flood—second-feet.	Maximum flood per square mile—second-feet.	Ratio of maximum to average flood.
NEW ENGLAND STREAMS.							
Connecticut River	Hartford	10,234	104	113,400	205,000	20.0	1.81
Merrimac	Lawrence	4,638	56	43,400	82,150	17.7	1.90
Androscoggin	Rumford Falls	2,090	40	24,900	55,500	26.6	2.23
Connecticut	Holyoke	8,144	26	73,000	115,000	14.2	1.58
Pemigewasset	Plymouth	615	24	16,800	30,640	49.7	1.82
Cobbossecontee	Gardiner	240	21	1,850	3,275	13.6	1.77
Kennebec	Waterville	4,270	18	59,600	151,000	35.4	2.53
Fomer	Holyoke	13	14	434	788	60.6	1.82

TABLE NO. 29—Continued.

Stream.	Place measured.	Drainage area—square miles.	Length of record—years.	Average yearly flood flow—second-feet.	Maximum flood—second-feet.	Maximum flood per square mile—second-feet.	Ratio of maximum to average flood.
Penobscot (West)	Millinockett	1,880	11	14,000	24,250	12.9	1.74
Penobscot	West Enfield	6,600	11	60,630	93,400	14.1	1.54
Kennebec	The Forks	1,570	11	13,720	19,890	12.7	1.45
Connecticut	Orford	3,305	11	31,700	49,700	15.0	1.57
HUDSON RIVER STREAMS.							
Hudson	Mechanicsville	4,500	23	44,500	108,000	24.0	2.42
Hudson	Ft. Edward	2,800	13	32,900	43,900	15.7	1.33
Mohawk	Dunsbach Ferry	3,440	12	50,500	84,200	24.4	1.66
East Canada Creek	Dolgeville	256	12	5,950	12,150	47.5	2.04
MIDDLE ATLANTIC STREAMS.							
Passaic	Dundee Dam	823	34	10,600	27,995	34.0	2.64
Neshaminy Creek	Low Forks	139	27	4,620	9,012	64.8	1.95
Perkiomen	Frederick	152	27	5,020	8,769	57.7	1.75
Tohickon Creek	Point pleasant	102	25	4,820	8,650	84.8	1.80
Susquehanna	Harrisburg	24,000	21	276,000	593,000	24.7	2.15
Susquehanna (West)	Williamsport	5,640	17	104,300	164,100	29.2	1.58
Potomac	Port of Rocks	9,650	17	114,000	218,700	22.7	1.92
Monocacy	Frederick	660	15	14,800	20,460	31.0	1.38
Delaware	Riegelsville	6,430	15	99,000	176,900	27.5	1.79
Schuylkill	Philadelphia	1,920	14	30,400	82,156	42.8	2.70
Shenandoah	Millville	3,000	13	44,800	139,700	46.5	3.12
Susquehanna	Wilkes-Barre	9,810	12	123,800	217,700	22.2	1.76
Susquehanna	Danville	11,100	12	143,250	304,800	27.5	2.13
Patapsco	Woodstock	251	12	6,890	11,100	44.3	1.61
Chenango	Binghamton	1,530	11	25,970	35,900	23.5	1.38
Juanita	Newport	3,480	11	63,500	118,000	34.0	1.86
Susquehanna	Binghamton	2,400	10	39,100	63,000	26.2	1.61
SOUTH ATLANTIC STREAMS.							
Savannah	Augusta	7,300	20	114,300	309,930	42.4	2.71
Ocmulgee	Macon	2,420	18	32,550	50,860	21.0	1.56
Black Warrior	Tuscaloosa	4,900	17	101,000	141,000	28.8	1.40
James	Buchanan	2,660	15	40,846	62,000	23.3	1.52
Cape Fear	Fayetteville	4,493	15	52,800	90,650	20.2	1.72
Yadkin	Salisbury	3,400	15	62,192	130,000	38.2	2.10
Chattahoochee	West Point	3,300	14	48,483	88,630	26.9	1.83
Coosa	Riverside	7,060	14	57,562	75,800	10.7	1.32
Broad of Georgia	Carlton, Ga	762	13	20,428	47,200	61.9	2.31
Oconee	Dublin	4,180	13	29,013	37,000	8.8	1.27
James	Cartersville	6,230	12	61,658	84,800	13.6	1.37
Coosawatte	Carters, Ga	531	12	12,500	17,700	33.3	1.42
Alabama	Selma	15,400	12	114,028	146,000	9.5	1.28
Etowah	Canton, Ga	604	12	13,440	19,000	31.5	1.42
Broad of Carolina	Alston, S. C.	4,610	11	76,400	131,000	28.5	1.72
Oostanaula	Resaca, Ga	1,610	11	23,661	39,200	24.4	1.66
James, N. Fk	Glasgow, Va	831	10	16,600	37,250	44.9	2.25
Tugalloo	Madison, S. C.	593	10	15,301	21,860	36.9	1.43
Flint	Woodbury, Ga	990	10	10,434	30,250	30.6	1.84
Tallapoosa	Sturdevant, Ala	2,500	10	36,247	59,100	23.7	1.63
Tombigbee	Columbus, Miss	4,440	10	34,476	50,420	11.3	1.46
OHIO RIVER BASIN.							
Ohio	Wheeling	23,800	50	294,000	480,000	20.2	1.63
Tennessee	Chattanooga	21,400	21	231,000	409,520	19.1	1.77
*Miami	Dayton	2,450	21	50,000	246,000	10.0	4.92
Clarion	Clairon, Pa	1,260	20	23,280	39,300	31.2	1.68
Upper Scioto	Near Columbus	1,032	16	19,300	68,000	65.8	3.52
Olentangy	Columbus	520	16	14,500	51,000	98.2	3.52
Lower Scioto	..do	1,570	16	33,800	119,000	75.7	3.52
Little Tennessee	Judson, N. C.	675	14	25,800	57,140	84.8	2.22
New	Radford, Va	2,720	13	64,200	137,760	50.5	2.15
Greenbrier	Alderson, W. Va	1,340	14	36,900	62,450	46.5	1.69
Tuckaseegee	Bryson	662	13	22,500	38,550	58.4	1.71
Hiwasse	Murphy, N. C.	410	13	12,300	22,360	54.5	1.81
French Broad	Asheville, N. C.	987	11	16,400	30,720	31.1	1.87
Tennessee	Knoxville	8,990	10	92,891	157,410	17.5	1.70
Hiwasse	Reliance	1,180	10	28,550	55,200	46.8	1.93

TABLE NO. 29—Continued.

Stream.	Place measured.	Drainage area—square miles.	Length of record—years.	Average yearly flood flow—second-feet.	Maximum flood—second-feet.	Maximum flood per square mile—second-feet.	Ratio of maximum to average flood.
ST. LAWRENCE RIVER BASIN.							
Genesee	Rochester, N. Y	2,365	128	22,100	50,000	21.0	2.26
Genesee	..do	2,365	12	22,400	36,500	15.4	1.63
Moose	Moose River, N. Y.	346	11	5,780	6,760	19.6	1.17
UPPER MISSISSIPPI RIVER BASIN.							
Mississippi	St. Paul, Minn	35,700	19	42,223	80,800	2.3	1.91
Pine	Pine River Reservoir, Minn	452	16	1,051	1,586	3.5	1.51
Mississippi	Above Sandy River, Minn	4,510	15	6,250	9,572	2.1	1.53
Chippewa	Chippewa Falls, Wis	5,300	11	36,454	64,400	12.1	1.77
MISSOURI RIVER BASIN.							
Kansas	Lecompton, Kans	58,550	60	81,000	221,000	3.8	2.72
Kansas	Lawrence, Kans	58,550	15	59,300	221,000	3.8	3.72
West Gallatin	Salesville, Mont	860	15	5,800	10,750	12.5	1.86
Platte	Columbus, Neb	56,900	14	25,000	51,100	.9	2.05
Madison	Red Bluff, Mont	2,085	13	6,500	10,275	4.9	1.58
Milk	Havre, Mont	7,300	13	3,919	9,600	1.3	2.46
North Platte, Neb	North Platte, Neb	28,500	13	17,640	25,500	.9	1.44
Cachela Poudre	Fort Collins, Colo	1,060	12	3,133	5,611	5.3	1.79
Loupe	Columbus, Neb	13,500	12	14,940	27,000	2.0	1.81
Bear Creek	Forkscreek, Colo	345	12	1,291	2,260	6.5	1.75
South Platte (S. Fork)	Denver, Colo	3,840	11	1,900	5,570	1.5	2.94
Republican	Junction, Kans	25,840	11	20,650	47,520	1.8	2.31
Blue	Manhattan, Kans	9,490	11	27,500	68,770	7.3	2.50
St. Vrains Creek	Lyons, Colo	209	10	982	1,280	6.1	1.30
LOWER MISSISSIPPI BASIN.							
Arkansas	Canon City, Colo	3,060	27	3,757	6,690	2.2	1.78
Arkansas	Pueblo, Colo	4,600	19	5,430	11,060	2.4	2.04
WESTERN GULF OF MEXICO.							
Rio Grande	Del Norte, Colo	1,400	17	4,350	7,670	5.5	1.76
Brazos	Waco, Tex	30,800	11	55,000	132,000	4.3	2.40
Colorado	Austin, Tex	37,000	10	43,000	72,600	2.0	1.69
GREAT BASIN.							
Bear	Collingston, Utah	6,000	21	6,550	11,600	1.9	1.77
Bear	Preston, Idaho	4,500	20	4,580	8,500	1.9	1.86
Provo	Provo, Utah	640	18	2,130	4,150	6.5	1.95
Humboldt	Golconda, Nev	10,800	15	1,400	3,160	.3	2.26
Humboldt	Oreana, Nev	13,800	14	1,260	3,047	.2	2.42
Humboldt (S. Fork)	Elko, Nev	1,150	13	1,120	1,478	1.3	1.32
Logan	Logan, Utah	218	12	1,390	2,450	11.2	1.77
Mill Creek	Salt Lake City, Utah	21.3	12	56	112	.5	2.00
Parley's Creek	..do	50.1	12	142	274	5.5	1.93
Carson (West Fork)	Woodward, Cal	70	12	900	1,570	22.2	1.75
Big Cottonwood	Salt Lake City, Utah	48.5	11	460	835	17.3	1.82
City Creek	..do	19.2	11	82	164	8.6	2.00
Ogden	Ogden	360	11	1,690	3,257	9.1	1.93
Truckee	Tahoe, Cal	519	10	774	1,340	2.6	1.74
Truckee	State Line, Colo.-Nev	955	10	5,260	15,300	16.1	2.91
Truckee	Vista, Nev	1,520	10	4,930	8,940	5.9	1.81
Weber	Unita, Utah	1,600	10	4,800	7,980	5.0	1.66
SOUTHERN PACIFIC COAST.							
Kern	Bakersfield, Cal	2,345	20	4,025	9,505	4.1	2.36
Sacramento	Jellys Ferry	9,300	15	129,000	254,000	27.3	1.97
Tuolumne	LaGrange, Cal	1,500	15	18,900	52,000	34.7	2.75
Kings	Sanger, Cal	1,740	14	19,000	43,930	25.2	2.31

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TABLE NO. 29—Concluded.

Stream.	Place measured.	Drainage area—square miles.	Length of record—years.	Average yearly flood flow—second-feet.	Maximum flood—second-feet.	Maximum flood per square mile—second-feet.	Ratio of maximum to average flood.
NORTHERN PACIFIC COAST.							
Columbia	The Dalles, Ore.	237,000	31	754,100	1,390,000	5.9	1.85
Willamette	Albany, Ore.	4,860	19	115,500	188,000	38.7	1.63
Spokane	Spokane, Wash.	4,000	18	23,550	35,200	8.8	1.50
Weiser	Weiser, Idaho	1,670	12	9,732	17,940	10.7	1.85
Umatilla	Gibbon, Ore.	353	10	3,808	10,000	28.4	2.63
Cedar	Ravensdale, Wash.	170	10	4,612	10,800	63.5	2.34

* Miami River rates are crest rates.

Mr. Fuller has shown that regardless of size or character of watershed, the ratio of the greatest flood to the average flood on each of our rivers, is much the same, viewed broadly and covering like periods of time. That is to say, a comparison on the ratio basis seems to eliminate size of drainage area and character of watershed, two of the most troublesome factors in the problem, and apparently reduces the differences to the chance combination of circumstances which may produce a great flood on a given watershed, and fail to occur upon another in a like period.

This method of comparison further permits, to some extent at least, a utilization of our relatively short American records to give us information that it might be expected a longer record might, upon the average, approximately substantiate. Thus, this method of comparison, apparently justifies the adding together of all the yearly records from all the rivers of the middle and eastern United States, setting down the yearly floods of each stream as ratios of the average of each stream, thus securing a composite record of great length as of one stream. The record thus produced by Mr. Fuller is some 1,672 years in length, and by arranging the ratios in the order of their magnitude, it was possible to draw valuable deductions on the theory of probability as to the flood ratio likely to occur upon any stream in a given period of years. With this ratio determined and the average flood of the given stream known, which can be approximately determined by a relatively small number of floods, a valuable deduction can be drawn as to the probable great flood and the likelihood of its occurrence in a given period of years.

A determination by this method is no more valuable, and probably not less valuable than the actuary tables of the life insurance companies. It cannot be expected to successfully predict the maximum flood upon any river in a given period of years any more than the actuary tables can show the life of a particular individual, but, in the long run in the indefinite future upon any stream, the conclusion based on the ratio method of comparison will probably fit the occurrences, and the least that may be said is that there is apparently no better means of determining the likely future occurrences.

LENGTH OF PERIOD AND PROBABLE RATIO.

If the procedure outlined above is granted, it is practicable to deduce mathematically the size of the ratio likely to occur in a given period of years. The following table is quoted from Mr. Fuller's paper, and shows the ratios that are likely to occur in the several yearly periods named.

TABLE NO. 30—RELATION BETWEEN FLOOD TO BE EXPECTED IN A SERIES OF YEARS AND THE AVERAGE YEARLY FLOOD.

(From paper on Flood Flows by Weston E. Fuller, American Society of Civil Engineers, October 15, 1913.)

Time in years.	Ratio of largest flood to average yearly flood.	Time in years.	Ratio of largest flood to average yearly flood.
1	1.00	50	2.36
5	1.56	100	2.60
10	1.80	500	3.16
25	2.12	1,000	3.40

Thus, in one year there is an even chance that the average flood will be equaled, in ten years the chances are even that a flood of 1.8 times the average will be equaled, and that in 1,000 years the chances are even that a flood will occur 3.4 times the average flood. In a way therefore, this procedure tends to fix a more or less definite maximum to provide for which, designs may be made, or, if the property to be protected is sufficiently valuable, or if many lives are to be protected as in the flood protection of a great city, the factor of safety can be provided and the works may be made adequate to provide against the greatest future contingency probable, with as liberal an allowance for error or the eccentricity of chance, as cost may permit or the value of the protection may warrant.

FLOOD RATIOS AT PEORIA.

It is practicable by the use of the rating curve at Peoria previously mentioned, to determine roughly, floods of past years. It will be instructive to compare these flood rates and determine their relation to the average flood at this place. A nearly continuous record is available at Peoria since 1867, a period of forty-eight years. Table No. 31 shows the five greatest floods within this period; the ratio of each to the average flood and the probable frequency of occurrence based on the forty-eight year record.

TABLE NO. 31—COMPARISON OF FLOOD RATIOS AT PEORIA.

Length of record—48 years. Average flood—40,800 second-feet.

Year.	Flood in second-feet.	Ratio to average flood.	Comparative expectancy —years.
1904	80,000	1.96	48
1913	73,000	1.78	24
1908	72,000	1.76	16
1892	68,000	1.66	12
1867	64,000	1.56	10

On the basis of the record at Peoria, we might therefore, expect a flood equal to that of 1904 once in forty-eight years, a flood equal to that in 1913 twice in forty-eight years, or once in twenty-four years, a

flood equal to that in 1908, three times in forty-eight years or once in sixteen years, that is to say, based on the record that exists, the chances would be even that the floods as stated would occur in the lengths of time mentioned. As to whether this record is sufficiently long to warrant conclusions as to frequency and magnitude is open to question.

FULLER FORMULA APPLIED TO RATIOS.

An examination of the above Illinois River data, and the large amount of flood data shown upon Table No. 29 would incline one to the belief that the broad experience on many rivers over long periods is of greater significance than the short period of record upon the Illinois. There seems to be no better means of applying this broad experience than the formula suggested by Mr. Fuller, which is in no sense theoretical, but is the concrete epitome of the most lengthy experience which it is possible to apply to the matter. Expressed mathematically, this formula is as follows:

$$R = 1 + 0.8 \log. T$$

in which

T = time in years, R = the ratio of the greatest flood rate likely to be expected within the time T to the average annual maximum flood of the stream.

Mr. Fuller has further summarized the large amount of data shown in Table No. 29 for the purpose of disclosing the average effect of the size of the drainage area upon flood rates, and demonstrates that the flood flows vary more nearly to the .8 power of the drainage area than any other single function of watershed size. Various other hydraulicians have placed this ratio as low as the .6 power, but there is probably no conclusion in this regard that is based upon so large an amount of data as that of Mr. Fuller. An examination of the average floods, as indicated by the rating curves at Peoria, Beardstown and Pearl varying from 13,000 to 26,000 square miles watershed area, indicates that this relation holds very nearly true for the Illinois River, Peoria and Pearl being in substantially exact agreement, and Beardstown varying from this rule not more than 10 per cent.

Table No. 32 is prepared from the Fuller formula, and indicates the flood rates most likely to occur once at the place named within the yearly periods stated.

TABLE NO. 32—FLOOD EXPECTATION IN VARIOUS PERIODS ON ILLINOIS RIVER.

Place.	Drainage area—square miles.	Average annual flood Q(are)—second-feet.	Coefficient C $= \frac{Q(ave.)}{A^{.8}}$	Maximum flood rate expectation—second-feet—once in—				
				16 years 1 + .8 log T=1.96.	30 years 1 + .8 log T=2.18.	50 years 1 + .8 log T=2.36.	100 years 1 + .8 log T=2.60.	1000 years 1 + .8 log T=3.40.
Peoria	13,479	40,250	20	79,000	87,750	95,200	104,800	136,900
Beardstown	23,444	62,500	18	122,000	136,500	148,000	162,500	213,000
Pearl	26,182	68,460	20	134,000	149,200	161,500	177,900	232,900
Mouth of river	27,914	....	20	141,000	157,000	170,000	187,200	245,000

T=Time in years. A=Drainage area in sq. miles. C=Coefficient of run-off.
Q=Rate of flow in second-feet. $Q(ave.)=CA^{.8}$. $Q(max)=CA^{.8}(1+.8\log T)$.

A comparison of these figures with those hereinbefore given, as indicated by the flood of 1904, indicate that the 1904 flood is one that should reasonably be expected about once in sixteen years, that a flood of about 95,200 second-feet may be expected at Peoria once in fifty years, a flood of about 104,800 second-feet once in one hundred years, and a flood of 137,000 second-feet once in one thousand years, with corresponding flood rates at Beardstown and Pearl as noted in the table.

If it is assumed that the flood of 1844 was about one-third larger than the 1904 flood at Peoria, or say, 110,000 second-feet, then this flood would have been the normal maximum flood in a 140-year period according to the Fuller formula. The flood actually occurred seventy-one years ago.

To some, the above reasoning may seem to involve too many assumptions to reach conclusions of merit. It is quite likely that time will come when the science of meteorology reaches a sufficient perfection (and that will be when it has a record behind it sufficiently long) to permit conclusions as to the size, shape and intensity of great rainstorms in the different localities of the eastern United States. At such time the above line of reasoning may be modified in that it may be practicable to narrow or widen the chances in certain localities, but at the present time there seems to be as good a chance for the great Ohio storm in 1913 to centralize on the Illinois River as to cover a great oblong as it did, spanning Indiana and Ohio, with the fringes of the storm in Illinois and Indiana. Until such matters are better understood, conservatism must assume that these great storms may happen anywhere in the general region of their occurrence.

CONCLUSIONS AS TO FLOOD RATES.

It will serve our present purposes to apply to the recently leveed Illinois valley the greatest flood that has left an authentic record of rate, namely the flood of 1904, and also to show the effect on water levels that would be occasioned by a flood about 35 per cent greater. Viewing the experience broadly of all the rivers in the country, these floods would approximately correspond to the record floods of sixteen years and fifty years respectively.

In the application of remedies for the conditions as they may be disclosed, it will be pertinent to consider the results that might be produced by even larger floods, and the data hereinbefore given will furnish a background for the ultimate probabilities of the future.

PART VII.

FUTURE FLOOD HEIGHTS AND THE EFFECT ON AGRICULTURAL LEVEES.

Having determined approximately the magnitude of the recent floods on the Illinois River, and the most probable flow rates to be expected hereafter, it now becomes possible to apply these floods to the modified river valley as existing today through the construction of levees, and as it will probably exist a few years hence when the levee districts now proposed are completed.

COMPUTED PROFILES.

Formulas and coefficients governing steady flow in uniform channels are well understood among engineers, and fairly definite values governing the ordinary conditions are in general use.

In a river, however, the conditions differ quite materially from the artificial channel under the usually assumed conditions of uniform flow, and while the flow formulas usually applied to the artificial conditions, are used, it is important to check the values in so far as this is possible by comparison with actual occurrences upon the stream under consideration so far as these occurrences can be determined and weighed.

CHEZY FORMULA.

The formula used in the following computations is the one perhaps most widely used by engineers in estimates of the flow of water in channels. The formula is as follows:

$$V = C\sqrt{rs}$$

in which V is the average velocity of the water in a given cross-section expressed in feet per second, C is a coefficient, r is the hydraulic radius in feet, and s is the slope.

In applying this formula to the conditions on the Illinois River, it is particularly important that the value C be determined under as many conditions as possible, for in this problem it will be necessary to deal with some very irregular cross-sections, especially where certain reaches of the stream are partly leveed, and at certain other places within the river valley it will be necessary to deal with cross-sections partly within the prism of the river channel and partly upon land where some of the floods have spread out to a great width with only a shallow depth.

It is believed that in view of the accurate topographical survey, and the large number of flow measurements during the 1904 flood, the values here shown merit considerable confidence.

In applying the flow formulas to the Illinois River conditions, it has been necessary to read slopes from gage records that are ordinarily recorded only to the nearest tenth. It was, therefore, thought necessary

to consider reaches of river not shorter than would produce in general two or three feet of fall so that errors in observation of slope might produce a minimum of effect.

All of the flow computations have been based upon an average cross-section for each reach considered, the average cross-section being the numerical average of a sufficient number of sections uniformly spaced to give a fair determination of the facts. In the long reaches the sections were about five miles apart.

BANK-FULL CONDITIONS.

Table No. 33 shows the result of computations to determine the prevailing flow coefficients under approximately bank-full conditions of the stream, that is, just prior to the water forsaking the channel of the stream and partially traveling by way of the bottom lands. A number of flow measurements were made at this stage of water, which has permitted fairly accurate estimates of the flows prevailing. It will be observed that the results are reasonably consistent for hydraulic computations. The value of "C" for the entire river averages 103, with a corresponding value of .0257 for "n" in Kutter's formula.

TABLE NO. 33—VALUES IN FLOW FORMULA DURING BANK-FULL CONDITIONS OF 1904 AT VARIOUS PLACES ON ILLINOIS RIVER.

GRAFTON TO KAMPSVILLE DAM.
Distance = 166,200 feet.

Date of discharge measurement.	Foot of reach.		Head of reach.									
	Elevation of water level—M. D.	Gage height—feet.	Elevation of water level—M. D.	Gage height—feet.	Fall—feet.	Measured discharge—C. F. S.	Measured velocity—feet per second.	Area average in reach—square feet.	Computed velocity average in reach—feet per second.	Mean depth average in reach—feet.	"C" average—$C = \frac{V}{\sqrt{rs}}$.	"N" from Kutter's Formula.
May 10	428.56	17.6	433.55	24.45	5.0	[1] 58,300	[1] 2.44	25,050	2.33	19.0	98	.0313
May 23	423.96	13.0	428.45	19.35	4.5	[1] 34,600	[1] 2.02	18,850	1.83	15.5	89	.0336
May 24	423.66	12.7	428.10	19.00	4.4	[1] 33,400	[1] 1.99	18,160	1.91	15.1	96	.0305
June 27	422.76	11.8	424.80	15.70	2.0	[1] 16,370	[1] 1.12	15,720	1.04	13.6	81	.0366
Averages of "C" and "N"	......	.....	......	.....	....	....	......	......	....	....	91	.0330

KAMPSVILLE DAM TO PEARL.
Distance = 61,800 feet.

Date of discharge measurement.	Elevation of water level—M. D. (foot)	Gage height—feet. (foot)	Elevation of water level—M. D. (head)	Gage height—feet. (head)	Fall—feet.	Measured discharge—C. F. S.	Measured velocity—feet per second.	Area average in reach—square feet.	Computed velocity average in reach—feet per second.	Mean depth average in reach—feet.	"C" average	"N" from Kutter's Formula.
May 21	429.73	20.60	431.53	11.83	1.8	[2] 31,800	[2] 2.33	16,670	1.91	12.6	100	.0270
June 3	427.48	18.35	429.12	9.42	1.6	[2] 27,450	[2] 2.56	13,840	1.98	11.1	117	.0220
June 24	426.43	17.30	427.62	7.92	1.2	[2] 17,460	[2] 1.86	12,840	1.40	10.5	95	.0284
Averages of "C" and "N"	......	.....	......	.....	....	....	......	......	....	....	104	.0258

PEARL TO VALLEY CITY.
Distance = 97,300 feet.

Date of discharge measurement.	Elevation of water level—M. D. (foot)	Gage height—feet. (foot)	Elevation of water level—M. D. (head)	Gage height—feet. (head)	Fall—feet.	Measured discharge—C. F. S.	Measured velocity—feet per second.	Area average in reach—square feet.	Computed velocity average in reach—feet per second.	Mean depth average in reach—feet.	"C" average	"N" from Kutter's Formula.
May 21	431.53	11.83	435.25	13.50	3.7	[2] 31,800	[2] 2.33	14,000	2.27	12.5	104	.0248
June 3	429.12	9.42	432.67	10.92	3.6	[2] 27,450	[2] 2.56	11,500	2.38	10.8	118	.0207
June 24	427.62	7.92	430.67	8.92	3.1	[2] 17,460	[2] 1.86	9,900	1.76	10.4	97	.0256
Averages of "C" and "N"	......	.....	......	.....	....	....	......	......	....	....	106	.0233

TABLE NO. 33—Concluded.

LA GRANGE DAM TO BEARDSTOWN.

Distance = 59,700 feet.

Date of discharge measurement.	Foot of reacu.		Head of reach.									
	Elevation of water level—M. D.	Gage height—feet.	Elevation of water level—M. D.	Gage height—feet.	Fall—feet.	Measured discharge—C. F. S.	Measured velocity—feet per second.	Area average in reach—square feet.	Computed velocity average in reach—feet per second.	Mean depth average in reach—feet.	"C" average—$C = \frac{V}{\sqrt{rs}}$	"N" from Kutter's Formula.
June 1	436.93	18.7	438.65	11.4	1.7	[3] 19,800	[3] 1.46	12,900	1.54	9.9	92	.0276
June 23	435.73	17.5	437.15	9.9	1.4	[3] 14,950	[3] 1.22	11,300	1.32	9.6	88	.0292
Averages of "C" and "N"	......	.....	......	.....	....	....	......	......	....	....	90	.0284

HAVANA TO COPPERAS CREEK DAM.

Distance = 89,300 feet.

May 28	442.87	11.2	444.05	16.3	1.2	[4] 16,650	[4] 2.22	11,360	1.47	9.7	129	.0203
June 21	440.97	9.3	442.25	14.5	1.3	[4] 12,120	[4] 1.94	9,350	1.30	8.8	115	.0219
July 12	439.37	7.7	440.75	18.0	1.4	[4] 9,830	[4] 1.90	7,650	1.28	7.8	116	.0209
Averages of "C" and "N"	......	.....	......	.....	....	....	......	......	....	....	120	.0210

COPPERAS CREEK DAM TO PEKIN.

Distance = 85,000 feet.

May 27	444.43	11.7	446.17	7.6	1.8	[5] 14,660	[5] 2.44	8,860	1.65	10.2	112	.0230
June 10	444.03	11.3	445.67	7.1	1.7	[5] 12,940	[5] 2.38	8,130	1.59	9.9	113	.0228
June 18	442.83	10.1	444.17	5.6	1.4	[5] 9,070	[5] 1.94	7,100	1.28	9.5	102	.0257
July 2	440.93	8.2	442.27	3.7	1.4	[5] 6,670	[5] 1.77	5,400	1.23	7.9	108	.0226
Averages of "C" and "N"	......	.....	......	.....	....	....	......	......	....	....	109	.0235

PEKIN TO PEORIA—LOWER BRIDGE.

Distance = 49,600 feet.

May 27	446.17	7.6	447.82	12.0	1.6	[5] 14,660	[5] 2.44	8,360	1.76	10.0	98	.0255
June 10	445.67	7.1	447.32	11.5	1.6	[5] 12,940	[5] 2.38	7,520	1.72	9.3	100	.0244
June 18	444.17	5.6	445.72	9.9	1.5	[5] 9,070	[5] 1.94	6,220	1.46	8.3	92	.0261
July 2	442.27	3.7	443.82	8.0	1.5	[5] 6.670	[5] 1.77	4,440	1.50	7.2	101	.0224
Averages of "C" and "N"	......	.....	......	.....	....	....	......	......	....	....	98	.0246

Numerical average of all observations	103	.0257

Explanation—
[1] Indicates measurements made by U. S. Engineers in 1904 at Twelve Mile Island.
[2] Indicates measurements made by U. S. Engineers in 1904 at Pearl.
[3] Indicates measurements made by U. S. Engineers in 1904 at Beardstown.
[4] Indicates measurements made by U. S. Engineers in 1904 at Havana.
[5] Indicates measurements made by U. S. Engineers in 1904 at Peoria.

FLOOD OF 1904.

It is seldom that a flood so accurately measured as the flood of 1904, passes through a valley so well determined by surveys, as are the bottom lands of the Illinois. It will be instructive therefore, to apply this flood

to the cross-sections and slopes prevailing at the time and determine what values must be applied in the flow formula to reproduce that which was observed.

Table No. 34 is a statement of the principal figures resulting from this computation.

It will be observed that the average values of C in the several reaches between Grafton and Peoria are much smaller than the values for C in the previous table covering bank-full conditions. The values of C under the 1904 flood flow conditions range from as high as 57 in the lower part of the river to as low as 26 in the reach between Beardstown and Havana.

Table No. 34 also shows the principal elements of the average channel section proper, that is, excluding the flooded bottom lands and considering only the channel of the river within its banks. The table shows an estimate of flow in the river channel based on C = 100. This flow has been compared with the total flow for the purpose of approximating the flow passing by land.

TABLE NO. 34—VALUES IN FLOW FORMULA DURING APEX OF MEASURED FLOOD OF 1904 AT VARIOUS PLACES ON ILLINOIS RIVER.

Note.—"C" refers to Chezy's Formula $V = C\sqrt{rus}$.

Date.	Reach.	Length of reach—feet.	Fall in reach—feet.	Total valley. Average flow—C. F. S.	Average section—square feet.	Average mean depth—feet.	Average "C".	Channel section. Average section—square feet.	Average mean depth—feet.	Flow assuming C = 100 C. F. S.	Land section. Average section—square feet.	Average mean depth—feet.	Flow—C. F. S.	Resulting value of "C".	Ratio of land flow to total flow—per cent.
Apr. 6	Grafton to Pearl......	228,000	9.3	122,000	114,500	8.5	57	31,000	17.5	83,000	83,500	7.2	39,000	28	32
Apr. 6	Pearl to La Grange Dam.......	182,000	6.4	113,300	130,850	7.1	55	27,000	14.6	62,000	103,850	6.2	51,300	33	45
Apr. 6	Grafton to La Grange Dam.......	410,000	15.7	118,300	122,000	7.9	56	29,000	16.1	72,000	93,000	6.7	46,300	31	39
Apr. 4	Beardstown to Havana.	164,200	4.1	95,000	218,050	10.9	26	21,070	15.9	42,300	196,980	10.8	52,700	16	56
Apr. 1	Havana to Pekin......	174,500	3.4	85,000	189,600	12.5	29	23,200	16.4	41,600	166,400	12.1	43,400	17	51
Mar. 28	Pekin to Peoria.....	49,600	3.6	81,000	74,100	11.5	38	23,000	17.6	82,000	51,100	10.1	—1,000	..	....
Apr. 4	Beardstown to Peoria...	388,300	10.5	89,000	183,000	11.4	28	20,000	16.0	43,500	163,000	11.0	45,500	13	51
Apr. 4	Grafton to Peoria.....	858,000	27.3	103,500	158,500	9.5	38	24,500	15.6	51,500	134,000	9.0	52,000	21	50

All this information would seem to indicate, that in general from 40 to 50 per cent of the flood traveled by way of the land, leaving from 50 to 60 per cent traveling by the channel proper. There are doubtless some places where the flow by land is much less than these average values.

EFFECT OF TREES.

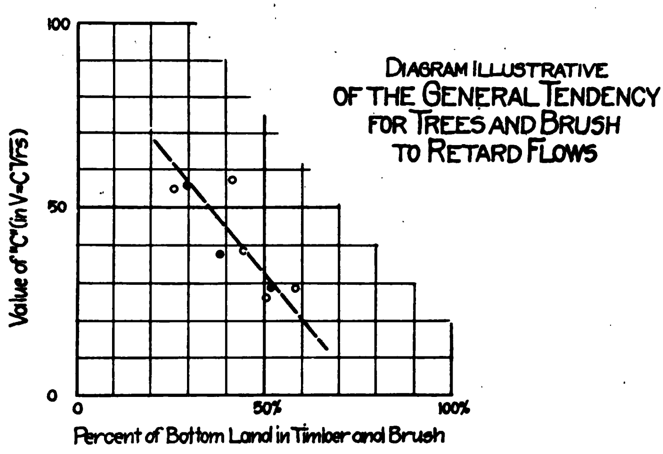
The reason was not apparent at first why the values of C were so much smaller in the middle reaches of the river than in the valley below the La Grange dam. An examination of the survey sheets, however, dis-

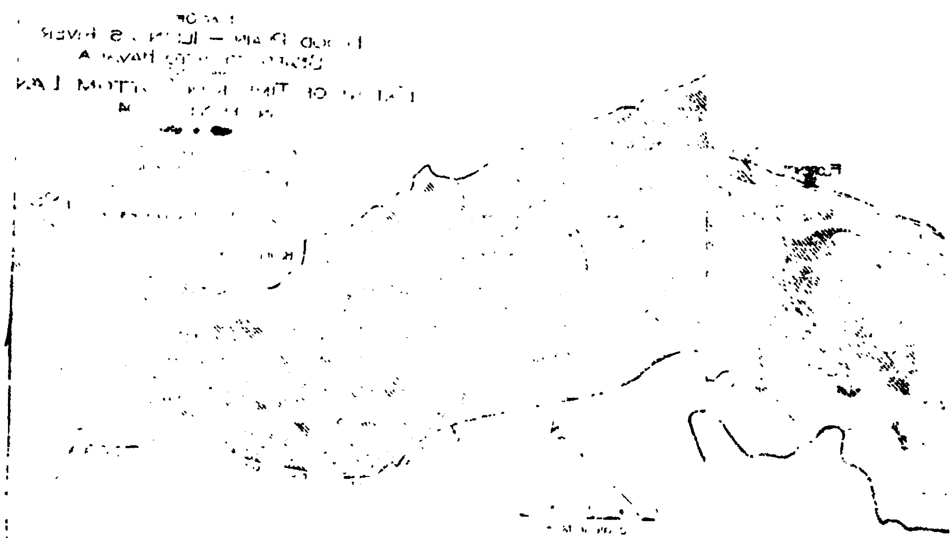
TABLE NO. 35.

TABLE AND DIAGRAM ILLUSTRATING THE EFFECTS OF TREES AND BRUSH UPON THE AVERAGE FLOOD FLOW VALUES IN CERTAIN ILLINOIS RIVER CROSS SECTIONS DURING THE FLOOD OF 1904

To Accompany the Report of
ALVORD & BURDICK
Engineers, Chicago

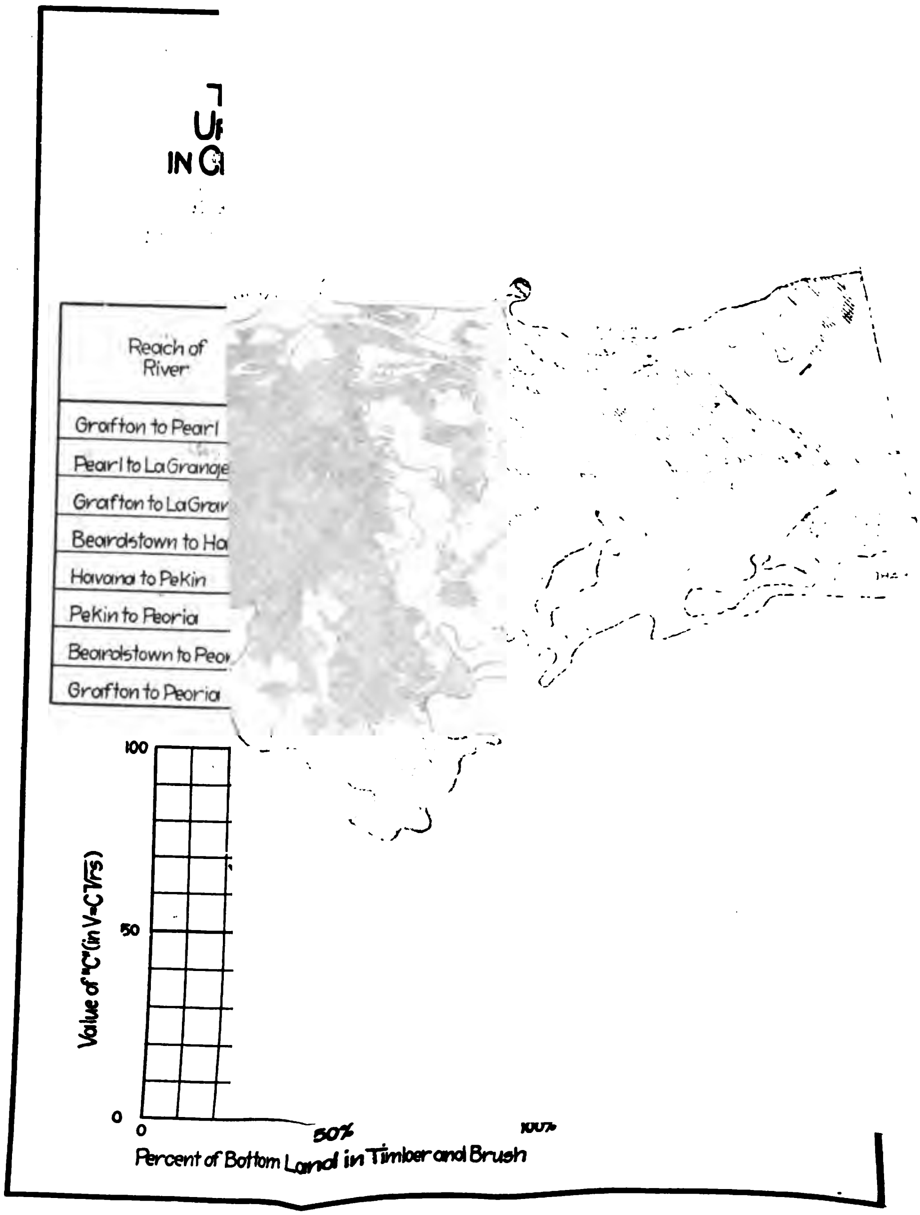
Reach of River	Average Value of "C" in Total Flood Cross Section of Valley at Apex of Flood	Approximate Percentage of Land in Timber and Brush
Grafton to Pearl	57	42%
Pearl to La Grange	55	23%
Grafton to La Grange	56	30%
Beardstown to Havana	26	42%
Havana to Pekin	29	58%
Pekin to Peoria	38	45%
Beardstown to Peoria	28	52%
Grafton to Peoria	38	39%

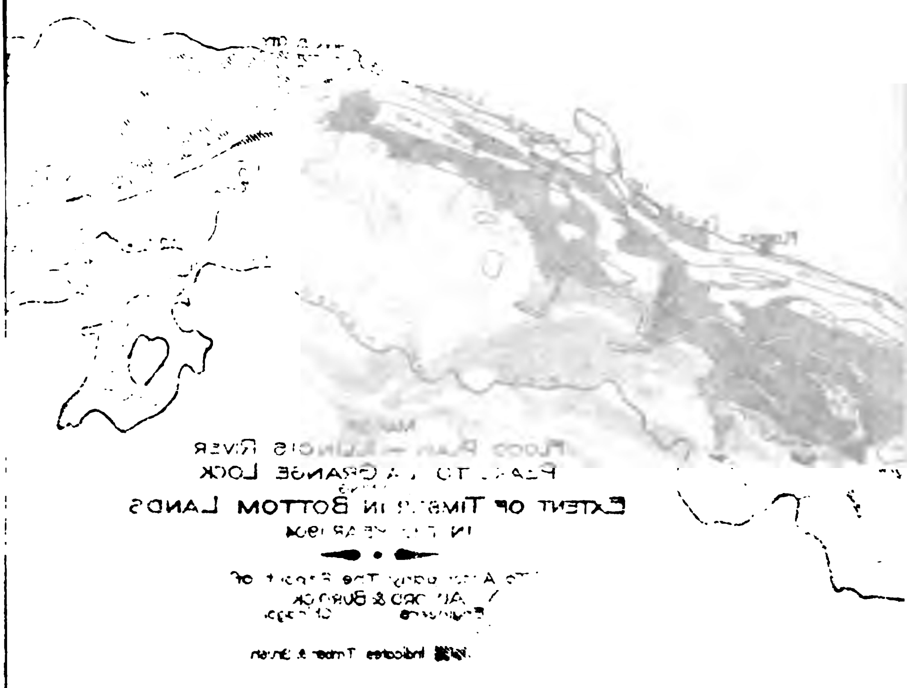




EFFECT OF TREES.

The reason was not apparent at first why the values of C were so much smaller in the middle reaches of the river than in the valley below the La Grange dam. An examination of the survey sheets, however, dis-




ILLINOIS RIVER
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closes the fact that although the mean depths were less below La Grange, the bottom lands were about 70 per cent cleared of trees and brush at the time of the survey 1902 to 1904, and presumably during the flood, whereas in the reach between Beardstown and Peoria, the bottoms were only about one-half cleared of timber and brush. The data seem to indicate that on the Illinois bottoms for the relations between stream cross-sections and valley cross-sections there prevailing, the bottoms about 30 per cent timbered, gave average C values of 56 as compared to 28 for cross-sections 52 per cent timbered. (See Table No. 35.) Figures 29 and 30 illustrate the timbered conditions in two of the reaches. It will be noted that the reach giving the lowest C value was much the more heavily timbered.

It is not expected that these figures are of general scientific interest. They would not be applicable to other streams without correction for the relation between the bottom land sections and the stream cross-sections proper. It is believed however, that the above information will be of material assistance in estimating flood heights under the changed conditions of the future, and to avoid being misled by some excessive flood heights of the distant past before any land was cleared.

TABLE NO. 36—TABLE ILLUSTRATING THE RELATIVE IMPORTANCE OF TIMBER AND BRUSH ON A COMPLETELY LEVEED REACH, I.E., FROM MILE 40 TO MILE 60—ILLINOIS RIVER IN FLOOD OF 1913.

	Section at—				
	Mile 40.	Mile 45.	Mile 49.7.	Mile 55.	Mile 60.
Total flood flow—area, square feet	35,500	42,800	32,850	35,100	26,400
Area in river channel, square feet	32,920	32,430	26,880	33,400	23,510
Per cent channel section to total	93%	76%	82%	95%	89%
Average	....	....	87%	....	....
Width of flooded section, feet	2,600	3,620	2,220	1,970	1,650
Width of channel section, feet	1,850	1,720	1,300	1,620	1,150
"Land Section" on Levee Side—					
Width, feet	150	430	370	150	300
Area, square feet	830	3,020	3,000	1,000	2,250
Per cent land area not cleared	53%	84%	81%	53%	77%
Average	....	....	70%	....	....
"Land Section" on "Bluff Side"—					
Width, feet	600	1,470	550	200	200
Area, square feet	1,750	7,350	2,970	700	640
Per cent land not cleared	....	....	....	....	....
Per cent of total flow cross-section over timber and brush land	1.2%	6.0%	7.4%	1.5%	6.6%
Average	....	....	4.5%	....	....

VALUES IN 1913 FLOOD.

It has previously been stated that in all probability, the flood of 1913 approximated the flow rates of 1904 very closely in the middle and lower river, with rates slightly less only as far upstream as Peoria.

As confirmatory in a general way of the similarity of these two floods, we take occasion to refer to Figures 31 and 32 which show the rainfall contours of the storm of March 17 to April 1, 1904, and March 20–27, 1913. It will be observed that in both storms the southeastern

part of the watershed received about 6" of rainfall. The total average rainfalls in these storms were as follows:

	Storm of March 17 to April 1, 1904.	Storm of March 20 to 27, 1913.
Rainfall in inches above Peoria	3.74	3.37
Rainfall in inches below Peoria	4.68	4.28
Total rainfall on watershed	4.24	3.86

It will be observed that so far as the total rainfall is concerned, these storms are quite similar. The 1904 storm however, covered a longer period.

In view of the fact that certain computations of future flood heights in places fall very close to the 1913 flood profile, it will be useful to determine what values probably existed in the 1913 flood. This has been done in Table No. 37. This table shows the interesting fact that in the reach of the river where the stream is fully leveed, the values of C correspond fairly well with the values previously tabulated for bank-full conditions, indicating that when the bottom lands are leveed off entirely, the problem of flood heights may be approached quite confidently using values of C of about 100.

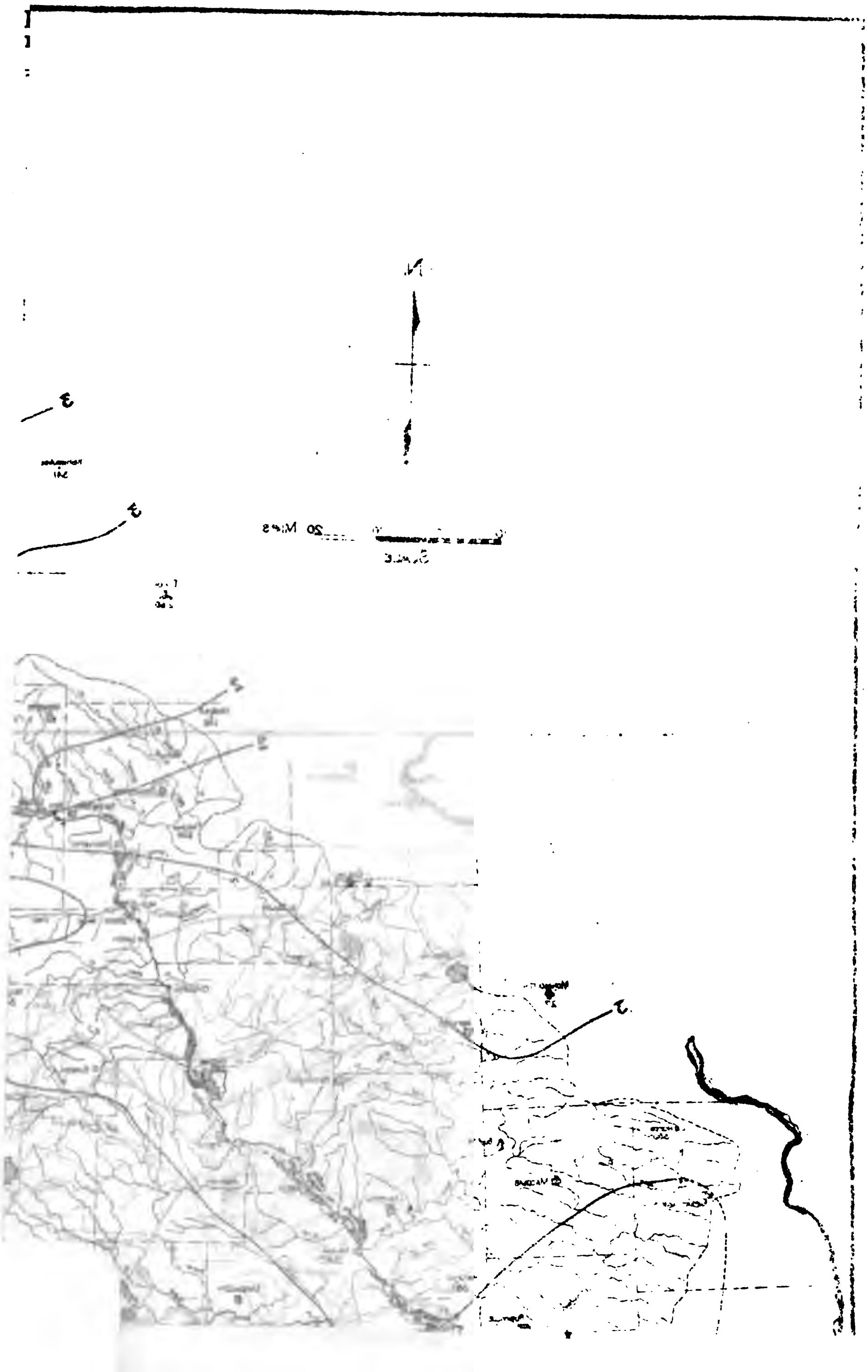
TABLE NO. 37—VALUES IN FLOW FORMULA DURING APEX OF FLOOD OF 1913, AT VARIOUS PLACES ON ILLINOIS RIVER—ASSUMING MAXIMUM FLOW RATE TO HAVE BEEN EVERYWHERE THE SAME AS IN 1904.

Date.	Reach.	Length—feet.	Fall—feet.	Average flow—C. F. S.	Average section—square feet.	Average mean depth—feet.	Average "C" in Chezy's formula $V = C\sqrt{rs}$.
Apr. 11	Grafton to Kampsville Dam	166,200	6.8	124,000	71,600	11.1	81
Apr. 11	Kampsville Dam to Pearl	61,800	2.1	115,000	32,300	16.0	*152
Apr. 11	Pearl to Valley City	97,300	5.7	114,000	34,300	15.6	110
Apr. 11	Valley City to Meredosia	50,200	.9	112,000	80,400	11.5	85
Apr. 11	Meredosia to La Grange Dam	34,300	1.1	111,000	96,700	15.0	53
Apr. 6	La Grange Dam to Beardstown	59,200	1.0	108,000	107,200	15.3	63
Apr. 5	Beardstown to Havana	164,200	2.5	95,000	201,400	11.8	35
Apr. 4	Havana to Copperas Dam	89,300	1.7	85,000	160,300	14.0	32
Apr. 3	Copperas Dam to Pekin	85,000	2.5	85,000	56,500	14.1	74
Apr. 2	Pekin to Peoria	49,600	2.5	81,000	69,800	12.7	46

* Data in this reach is not reliable on account of a break in the levee of the Hartwell District.

FLOW RATES.

We have hereinbefore given a table (No. 27) showing our conclusion as to the flow rates that prevailed at various places upon the Illinois River during the flood of 1904. These data have been used in the computed flood profiles hereinafter given, interpolating between observation points in the table in accordance with tributary drainage areas.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In the computation of profile for a flood 35 per cent larger than that of 1904, it has been assumed that the flood would be 35 per cent greater in rate to every place upon the river considered.

FLOW VALUES USED IN COMPUTATIONS.

In the computations of the profiles of future floods, we have in general been guided by the data hereinbefore presented, and further, upon close observation of the effects that have been produced heretofore under conditions as nearly similar as possible to the probable results in the estimate of particular profiles.

It will be noted that much of the data points toward the conclusion that for Illinois River "channel conditions," as distinguished from those conditions where bottom lands are overflowed, the value of C in the Chezy formula approximates 100, or reduced to value of n in Kutter's formula under the general depth and slopes prevailing approximately, $n = .026$.

Between Beardstown and Kampsville, a distance of some sixty miles, the river is now very largely confined by levees, and the channel conditions are very largely similar to those of artificial channels, except in cases where the cross-sections are more or less broken up through the partial reclamation of the bottom lands. We have used values of C approximating 100 for the conditions of the re-occurrence of the 1904 flood in the river valley leveed as at present, and have used higher values for C under the circumstances where the same flood might enter the Mississippi River at a higher level as in 1844. These variations in the value of C in general range from 100 to 108, the value being varied in accordance with the mean depth and slope, as would be indicated by substituting these values in Kutter's formula for C.

Above Beardstown, nearly all the reaches are more or less affected for long distances by the flooding of bottom lands at all stages of water considered, and in computing flood heights under various conditions of flow, the reasoning has been as close as possible from known results under known circumstances. In most cases values were substituted in the flow formula, values being used that were indicated by the nearest comparable known circumstance. In some cases where the computed flood differed slightly from an observed flood of known volume, it was only necessary to correct the slope for difference in stage, resulting velocities and mean depth, to ascertain approximately the profile for the changed condition.

To sum up therefore, theory has been used in the computation of these flood profiles only as it might be useful to reason intelligently from the nearest similar known condition to the condition upon which information was desired.

FLOW VALUES OBSERVED ON OTHER RIVERS.

For comparative purposes we would show herewith, Table No. 38, which is compiled from a treatise by Ganguillet and Kutter. We show only the experimental flow values in instances where the depths and velocities were somewhat comparable to those upon the Illinois. It will

be observed that data on other streams conforms fairly well to the tabulated observations on the Illinois.

TABLE NO. 38—TABLE SHOWING "C" AND "N" VALUES ON VARIOUS RIVERS FROM TABLE BY GANGUILLET AND KUTTER.

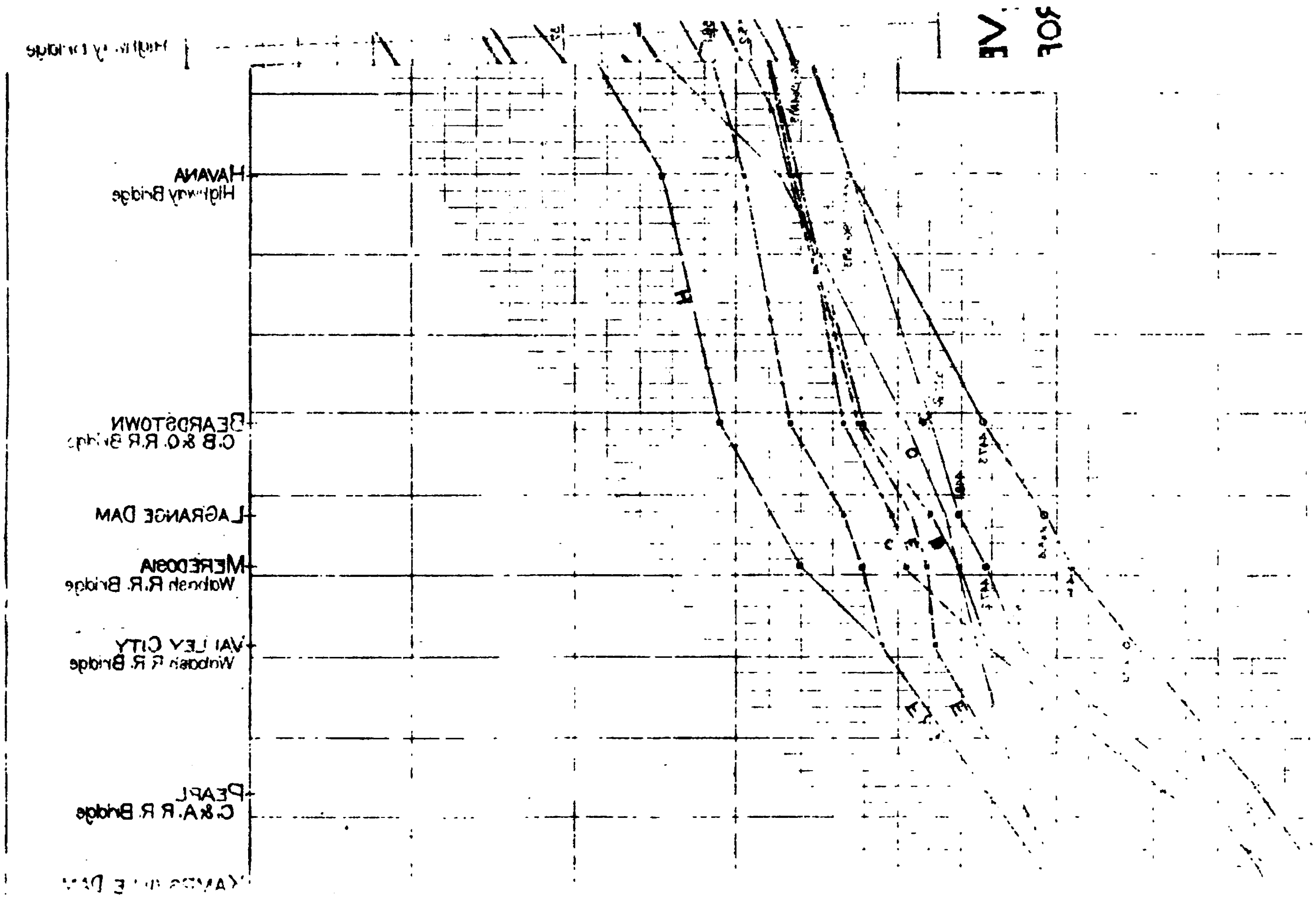
Ganguillet and Kutter.	Hydraulic radius.	Velocity—feet per second.	"C" value.	"N" value
Weser	6.3 to 13.6	3.5 to 5.1	81 to 101	.020 to .025
Tiber	9.46	3.41	97.1	.0228
Elbe	17.5	8.0	86.3	.0275
Saone	10.9 to 15.8	1.9 — 2.4	89 — 98	.027 —.030
Seine at Paris	10.9 to 18.4	3.7 to 4.8	92 — 108	.023 —.026
Seine at Meulan	11.2 to 17.9	2.3 to 3.3	86 — 93	.026 —.029
Rhine at Neuburg	13.91	5.84	78.9	.0297
Rhine at Pforz	13.94	5.64	79.8	.0294
Rhine at Delta	11 to 16	3.0 to 3.5	89 — 98	.022 —.029
Rhine at Delta	11 to 17	3.0 to 5.0	81 — 99	.024 —.030
Danube	12 to 14	2.2 to 2.5	87 to102	.0247—.0287
Bayou LaFourche	13 to 16	2.7 to 3.0	116 to 130	.0195—.0225
Bayou Plaquemine	15.3 to 18.4	4.0 to 5.2	84.4 to 84.5	.0292—.0296
Great Nevka	17.42	2.05	127.3	.0252
Missouri	11 to 18	3.0 to 6.2	90 to 107	.023 —.0254
Average of all (excluding extremes)	....	....	93	.026

FUTURE FLOOD HEIGHTS.

With the aid of the data hereinbefore described, we have estimated the height to which the flood waters will probably rise in the improved river valley under several conditions as set forth on Fig. 33.

Fig. 33 shows the water profiles from Grafton to Peoria. Three observed flood lines are shown, the full lines A, B and C,—"A" representing the flood of 1904, "B" representing the flood of 1913, and "C" representing the flood of 1844. The first and last floods passed through a practically virgin valley with no levee districts. The flood of 1913 passed through a valley almost completely leveed below Valley City.

Fig. 33 further shows the computed profile of the 1904 flood, assuming this flood to be repeated under present conditions with levee districts now under construction completed, it being assumed that the flood enters the Mississippi River at the same elevation as in 1904. It will be observed that in the lower eighty miles of river this water surface follows quite closely the actually observed flood in 1913. It is estimated that the maximum variation from the original 1904 flood would occur in the vicinity of Valley City, at which place the water would be about 4 feet higher than in 1904. This difference remains substantially the same up as far as Beardstown, above which place the difference gradually becomes less, and it is estimated that at Peoria the retarding effect of the leveed districts downstream has been very nearly lost. The line marked "G" is the computed water profile of a 1904 flood, assuming it to pass through the Illinois River valley when all the levee districts now projected are completed. It will be observed that this would cause the water to rise a little over 5 feet higher at Meredosia than it did in 1904; in fact, nearly 2 feet higher than any water has reached at this place. At Havana, curve "G" very nearly coincides with curve "D," but in the vicinity of Copperas Creek they again separate on account of the proposed levee districts in that vicinity.


HAVANA
Highway Bridge
BEARDSTOWN
C.B.&Q. R.R. Bridge
LAGRANGE DAM
MEREDOSIA
Wabash R.R. Bridge
VALLEY CITY
Wabash R.R. Bridge
PEARL
C.&A. R.R. Bridge
H
E
F
G
D
C

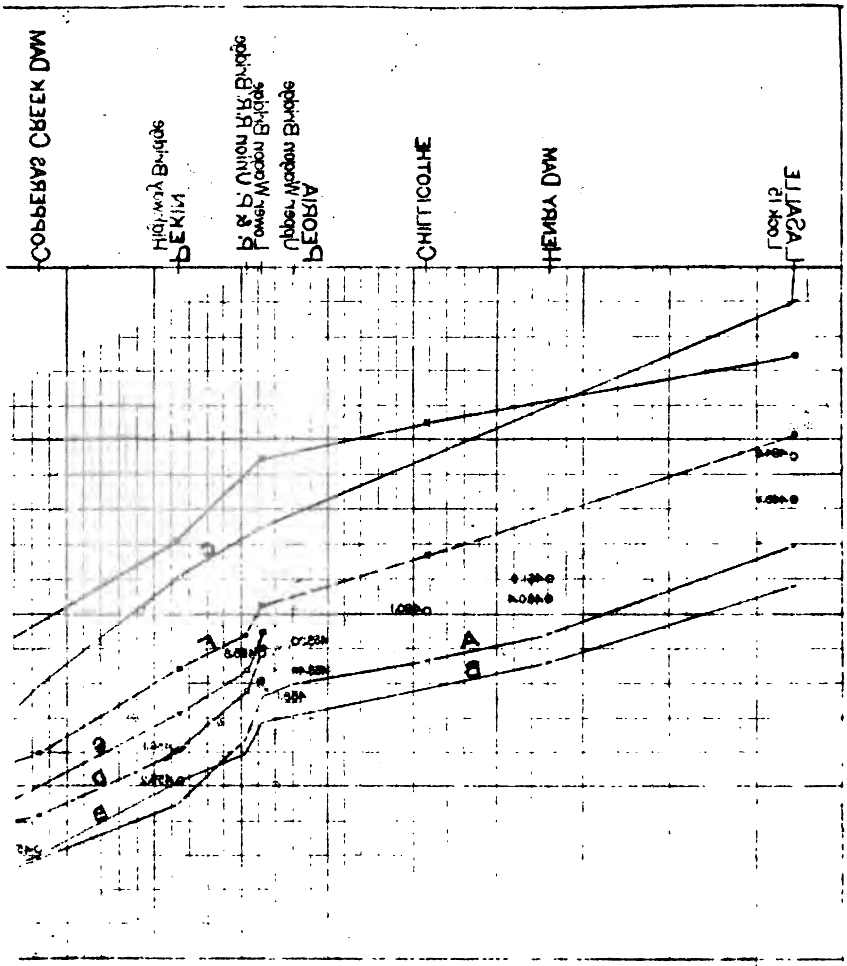


DIAGRAM SHOWING

MAXIMUM FLOOD PROFILES

OBSERVED and COMPUTED

ILLINOIS RIVER

Engineers Chicago

LEGEND

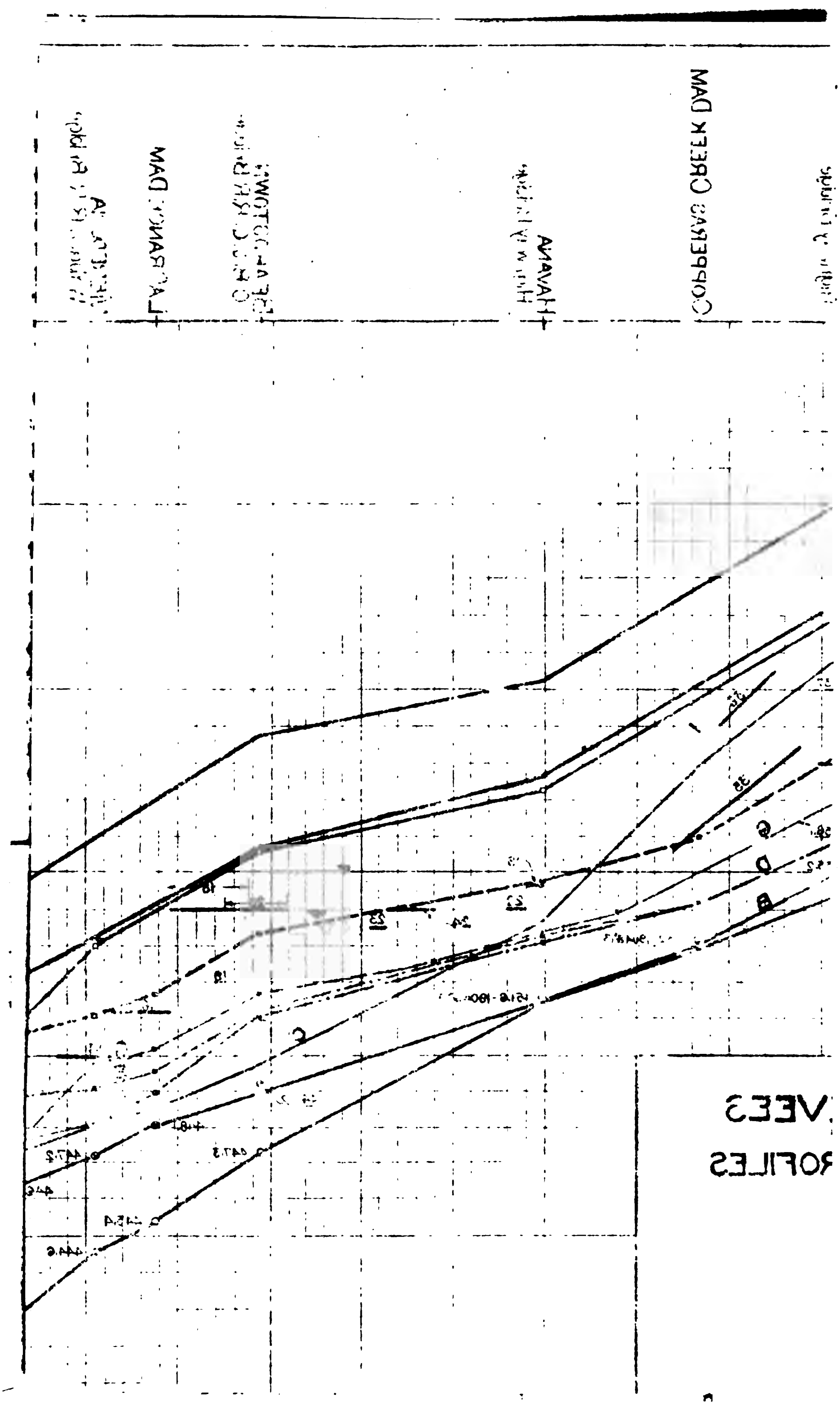
A - Flood of April 1904 ○ Indicates maximum stage in this flood.

B - Flood of April 1913 ●

C - Computed profile of 1904 flood ... under present conditions ... completed

E - Computed ... flood assumed ...

F - ... about 35 percent ...


COPPERAS CREEK DAM
HAVANA
VEES
ROFILES

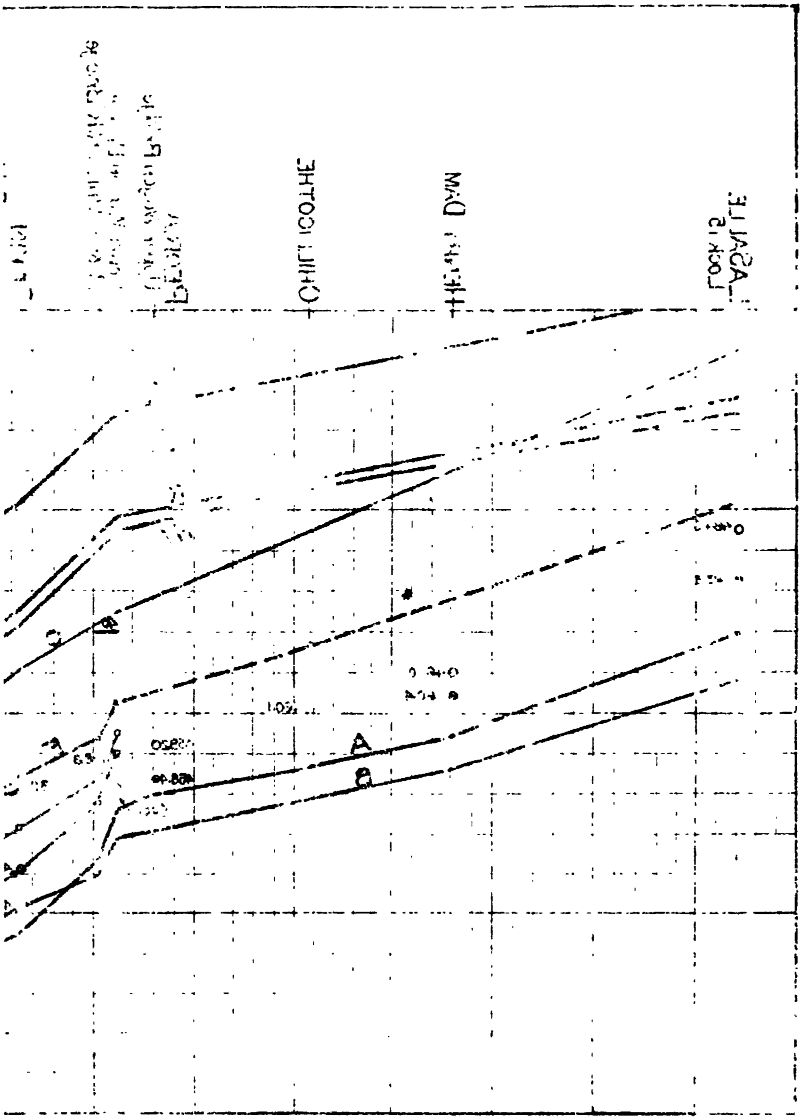


DIAGRAM SHOWING

CREST ELEVATION OF LE

COMPARED WITH

OBSERVED FLOOD PF

ILLINOIS RIVER

Report of

ALVORD & BURDICK

Engineers Chicago

LEGEND

A - Flood of April 1904 ... maximum ...

B - Flood of April ...

C - Highest water ... of 1844.

HIGH MISSISSIPPI LEVELS.

It is pertinent to inquire what would happen should the flood of 1904 be repeated with the bottom lands leveed as at present, and with the Mississippi at the height prevailing during the flood of 1844. This condition is illustrated on Fig. 33 by line "E." It will be observed that the computed line "E" lies above the flood of 1844 for the reach of river between Pearl and Havana. The curve "E" intersects the curve "D," which was the same flood entering the Mississippi at the low level as in 1904 in the vicinity of Copperas Creek. This indicates that for large floods having about the flow rate of 1904, the effect of the Mississippi River stage disappears below Peoria.

For the purpose of illustrating a condition that may occur but probably rarely, we show on Fig. 33, the profile "F" which is the computed height to which the water would rise, assuming a flood about 35 per cent greater than the flood of 1904 should pass through the valley under present conditions, with levees under construction completed, and enter the Mississippi River at the flood level of 1844.

It has been elsewhere estimated that a flood of this delivery might reasonably be expected to occur about once in fifty years. It would be natural to expect that the Mississippi would be relatively high at the time of occurrence of such a flood. In assuming that this large flood is delivered to the Mississippi at the flood height of 1844, which is the greatest flood of record on the Mississippi River in over one hundred years, we have probably fixed flood heights, especially in the lower river, that are not likely to be exceeded once in fifty years. It is quite conceivable that even a flood of greater volume might occur at any time. The probability of its occurrence on the apex of a record Mississippi flood is not very great.

ABOVE PEORIA.

The computations have been carried upstream only so far as Peoria for the reason that the developments above this place, including those in prospect, are not sufficiently great to have an important effect upon the flood profiles. The developments are very largely in prospect and not well matured. It is therefore thought to be inadvisable to attempt to reason out the small variations in river levels that might be occasioned by the proposed districts.

GAGE HEIGHTS AND LEVEE DISTRICTS.

Fig. 34 shows the observed and computed water profiles hereinabove described, and also the profiles of the levee tops on the Illinois River so far as we have been able to determine them. This figure is prepard for the purpose of showing the adequacy or inadequacy of the existing levees to protect the land against future floods.

Upon this drawing we have used the standard levee profiles as indicated by the dotted lines on Fig. 23. These profiles have been used as representing the levee top that it is endeavored to maintain in each district, the levee actually existing varying more or less from time to time as it may be reduced in height by weathering or as it may be increased in height to provide additional protection. An examination

of Fig. 34 indicates that all the levees are of sufficient height to withstand the flood heights of 1904 and 1913, although at the time of occurrence at least one district was over-topped by the latter flood.

The flood height of 1844 would inundate about half of the existing districts.

The flood of 1904 might be repeated in the river valley as now improved without over-topping any of the levees. One district would however, be over-topped if the same flood occurred in the river valley with all the districts completed as now proposed.

If the flood of 1904 should be repeated in the river valley as now existing and should enter the Mississippi at the height of the 1844 flood, about one-third of the levee districts would be over-topped—all of those districts lying below Meredosia.

If a flood exceeding in amount the flood of 1904 by about 35 per cent, should be repeated in the present valley, and should enter the Mississippi at the flood height of 1844, then about two-thirds of the levee districts would probably be over-topped. A few districts near Valley City, Beardstown and Pekin would probably escape.

It will be observed that the standard levee grades are what might be called only slightly deficient, the lowest lying not more than 3 feet below the maximum flood height on figure 34.

PROPER LEVEE HEIGHTS.

If these levees protected a great city where a failure of the levee would entail great loss of life, as at Dayton during the flood of 1913, and great damage to property, then there should be considered quite materially greater flow volumes than we have herein considered, and consequently, greater heights of water under the conditions of the leveed river valley present and future. Under such circumstances we would be warranted in considering contingencies more remote than have been considered herein.

In the Illinois River valley, levees protect farm land only. A failure is not likely to produce loss of life, for in flood, levees are very carefully watched, and if a levee is over-topped, the inhabitants are usually prepared to leave some time in advance of the event. The damage from flooding will be nominal except for the loss of a crop. The flooding of a district about once in fifty years would not seem to involve sufficient damage to incur great expense to provide against flooding, but when the ability to readily sell the land is considered, it is probable that a liberal factor of safety in the height of the levees is justified. It will be readily seen that where at all possible, levees should extend sufficiently above the maximum water level to guard against the danger of over-topping through wave action and wash.

PART VIII.

DISCUSSION OF REMEDIES.

The preceding chapters have shown that the agricultural levee districts have grown and encroached upon the river bottoms to such extent that they endanger themselves by restricting the flood water channel and increasing the flood heights to such amounts that many districts must be flooded when an unusual freshet occurs.

It has further been shown that the fish yield which rapidly increased up to 1908 has since that time rapidly declined, having been greatly affected by the reduction in breeding and feeding grounds brought about through the construction of agricultural levee districts and the exclusion of the flood waters from these lands, on which flooded lands the fish breed and the early development of the young fish takes place.

It remains to select the best remedy for these unfavorable conditions and tendencies, and in so doing, it will perhaps, be most useful briefly to point out the various remedies more or less applicable to the existing situation to show how each would affect the problem in hand, and if possible, to select from these remedies, the one best fitted to accomplish the maximum of good in the light of the circumstances as they exist at present and in the future so far as we are privileged to read the future.

In the application of corrective measures, it will be kept in mind that the bottom land levee districts are producing at the present time agricultural products to the value of about three million dollars per annum, at the average prices of the past few years. There is good prospect that this yield will soon be increased to six or seven million dollars. The Illinois River fishery in 1908 yielded $721,000 with fish at an average price of three cents per pound. At European wholesale prices, ten to fifteen cents per pound, this catch would have been worth from two and one-half to three and one-half million dollars. Nineteen hundred and eight was a banner fishing year.

It would seem therefore, that from a financial standpoint, agriculture is the predominant interest, but that the fisheries have great future possibilities and should be given all possible consideration in the improvement of the Illinois River valley conditions.

OUTLINE OF REMEDIES.

It is doubtful if anyone will seriously consider the abandonment of the investments in the valley and the reverting to conditions of nature which would be likely to correct the present difficulties. For obvious reasons it is out of the question that we go back to the days of the buffalo and the Indian.

Referring particularly to the flood situation, the remedies are of two classes, first, channel improvements, and second, storage.

Channel improvements will include all means of providing a more adequate waterway for the passage of the floods. This may be accomplished in a number of ways as follows:

(a) Through increasing the height of the agricultural levees, thereby permitting the flood waters to occupy a greater cross-section without flooding the farm lands.

(b) Through lowering the bed of the channel, perhaps through cooperation with one of the several plans for a deep waterway.

(c) Through greater widths between levees where same are built on both sides of the stream or elsewhere by setting the levees back at greater distances from the river. This is hardly a practicable remedy where the levees have been built. It is easily applicable, however, to future levee construction.

Storage if properly applied, will be efficacious in reducing the rate of flow at critical periods in a flood, and hence it would have a tendency to reduce maximum flood heights. Storage may be beneficially applied to the Illinois River in two ways:

(a) Through storage in the Illinois River bottoms,

and

(b) Through storage in the valleys of the tributaries.

It will be useful to this problem to determine approximately how far each of these remedies might be effective, and as the effects of some of them are quite complex, it will be well to examine them carefully. Storage is, perhaps, the most difficult to apply, and as it has some attractive possibilities, we will consider it first.

FLOOD ABATEMENT BY STORAGE.

The reduction of floods through storage, although it has only lately claimed public attention in this country, is not a new remedy either at home or abroad. Europe furnishes us numerous examples of large reservoirs built for the storage of flood waters; and particularly in France, in Spain and in Germany, the practice has been followed more or less for two hundred years. Within the last twenty years, a great number of these reservoirs have been built in Germany and in Austria.

In the United States six very large reservoirs have been built for the control of the Upper Mississippi River. This work was started in 1881, and completed in 1895. Perhaps the chief duty of these reservoirs is the improvement of low water conditions in the Upper Mississippi, but they have also a marked effect upon the flood heights above St. Paul.

The Pittsburgh Flood Commission reporting under date of April, 1912, recommended storage reservoirs as a correction for the flood conditions of the Ohio River at Pittsburgh.

Reservoirs were considered for the flood protection of Columbus, Ohio, and while channel improvements were selected as the most effective remedy, it was demonstrated that reservoir sites in the valleys of the rivers adjacent to Columbus aggregating about 125,000 acre-feet, would have been effective in reducing a 140,000 second-feet flood to about 78,000 second-feet, a reduction of 45 per cent. This was on the Lower Scioto River having a drainage area of 1,570 square miles.

Storage reservoirs have been adopted as the remedy for the conditions producing the Dayton disaster on the Miami River. It is estimated that seven reservoirs having a capacity of 60,000,000,000 cubic feet, or 1,400,000 acre-feet, would have been effective in reducing the March, 1913, flood of 250,000 second-feet from a drainage area of 2,500 square miles by the amount of 75 per cent.

TENDENCY OF LEVEES TO INCREASE FLOW RATES.

Elsewhere in this report it has been pointed out that the storage in the capacious bottom lands of the Illinois River tends to reduce the maximum rate at which the water is delivered to the Mississippi, and also to a certain extent, to reduce the flow at all places on the Illinois River.

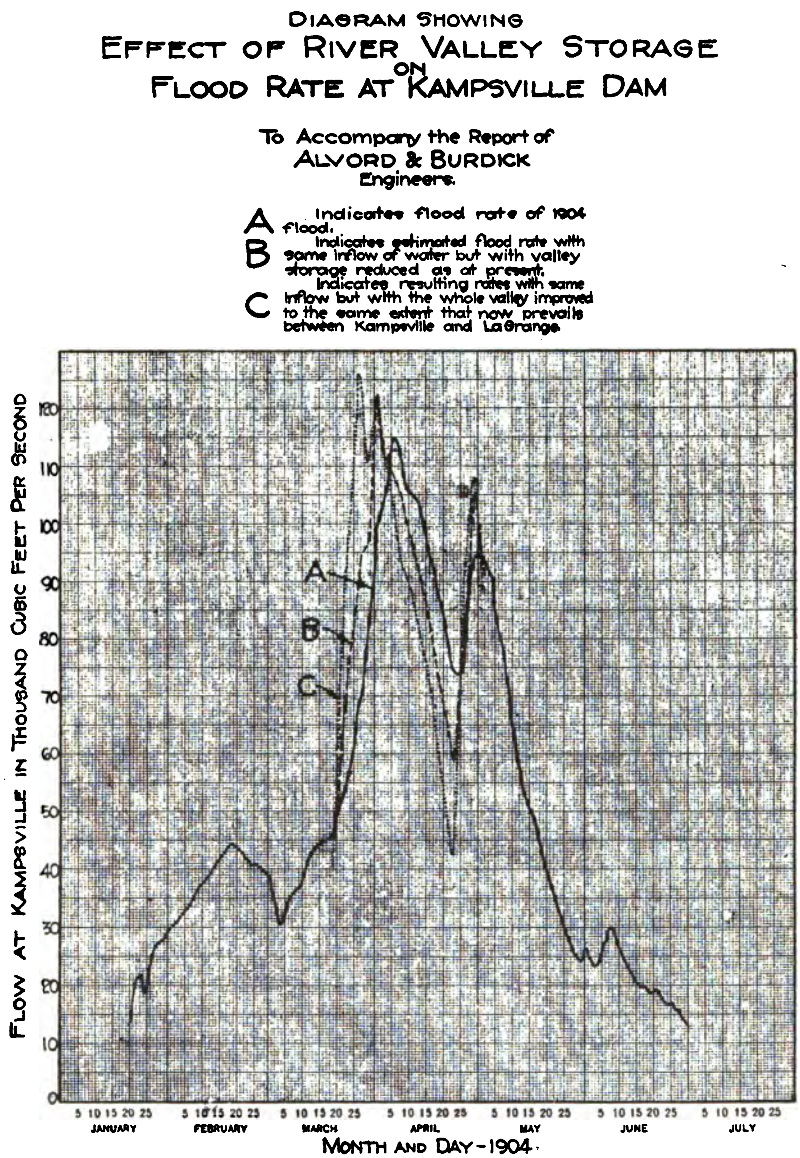


FIGURE 35.

The construction of the agricultural levee districts has not only decreased the cross-section through which the flood waters might escape, but has also robbed the valley of a large part of its storage, thereby tending to increase the rate of run-off in the stream.

Elsewhere in this report we have presented diagrams giving the area in the river valley that is overflowed at various heights of water. From these diagrams it is practicable to compute the volume of the storage in the river valley when the same is flooded to any depth below the high water of 1844, the highest water of record.

In order to determine approximately the effect of the levee operations on the maximum flood flow rate, we have prepared Fig. 35 which is a hydrograph of the flow rates estimated to have existed at the Kampsville Dam during the flood of 1904. This hydrograph is based on the rating curve at Pearl a short distance above Kampsville, and although it is doubtless more or less in error, particularly in the latter part of the flood through the influence of the Mississippi River, it is believed to represent the facts with sufficient accuracy to determine approximately the effect of the bottom lands' storage.

Referring to Fig. 35 the line marked "A" is the hydrograph of flow of the 1904 flood. It will be observed that this flood reached a maximum of about 115,000 second-feet.

Line "B" represents the estimated flow rates near the apex of the flood should the flood of 1904 be repeated, but with the valley storage reduced as at present, with the districts under construction completed. Under these conditions it is estimated that the run-off rate at Kampsville would be 121,000 second feet.

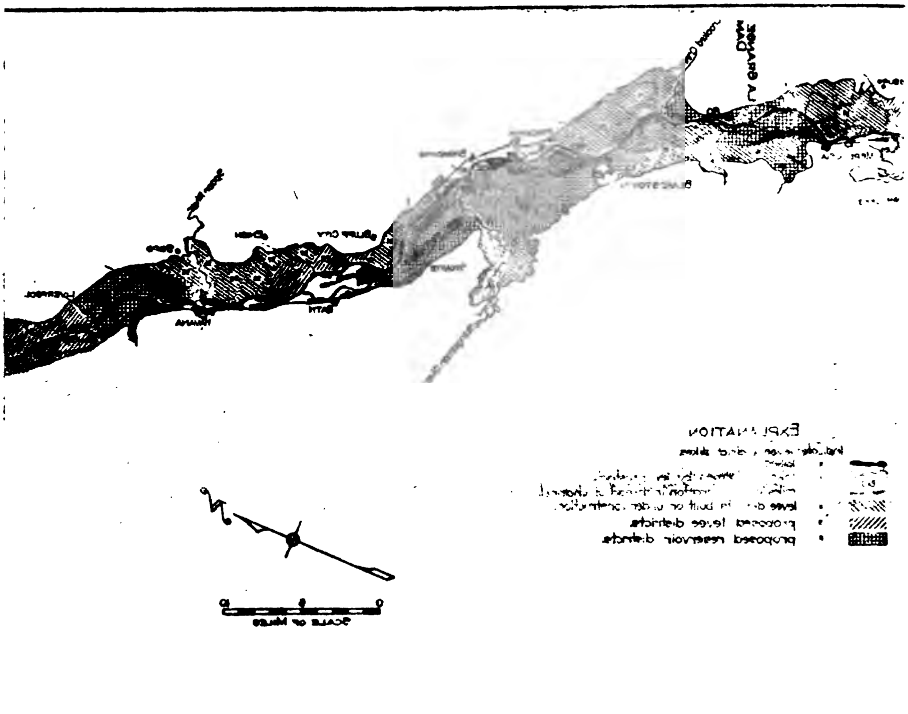
Curve marked "C" is the estimated flow rate near the apex of the flood, assuming the inflow to the river valley to have been the same as in the flood of 1904, but with the whole valley improved to the same extent that now prevails between Kampsville and LaGrange, that is, assuming that practically the entire river from Kampsville to La Salle is confined between levees. Under these circumstances, it is estimated that the inflow of the valley in 1904 would have resulted in a flood rate of 126,000 second feet at Kampsville.

These modified flow hydrographs have been estimated upon the assumption that the rate of flow passing Kampsville is the summation of the inflow rates to the river valley plus or minus the gain or depletion in the river valley storage as produced by rising or falling stages.

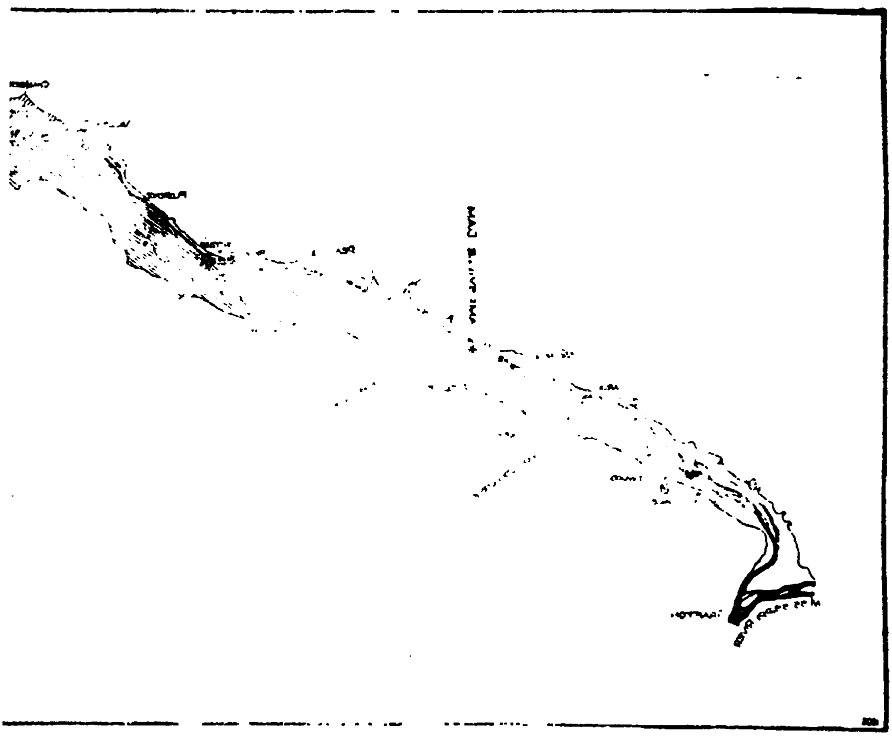
Inasmuch as crest rates were principally of significance, it was not thought necessary that the computation should cover the entire flood. In estimating the amount of water going into and coming out of the valley storage, the river was taken section by section. This was necessary inasmuch as at some times during the flood, the storage was building in certain parts of the river, and depleting at certain other places above Kampsville.

The total storage in the levee districts as now completed, or in process of construction above Kampsville between low water plane of 1901 and the high water plane of 1904, is estimated at 920,000 acre-feet.

The total amount of storage above Kampsville within all levee districts, assuming that the river is leveed-in about to the same extent as



EXPLANATION
levee districts built or under construction
proposed levee districts
proposed reservoir districts
SCALE OF MILES
LA GRANGE DAM
BEARDSTOWN
BLUFF CITY
BATH
HAVANA
LIVERPOOL



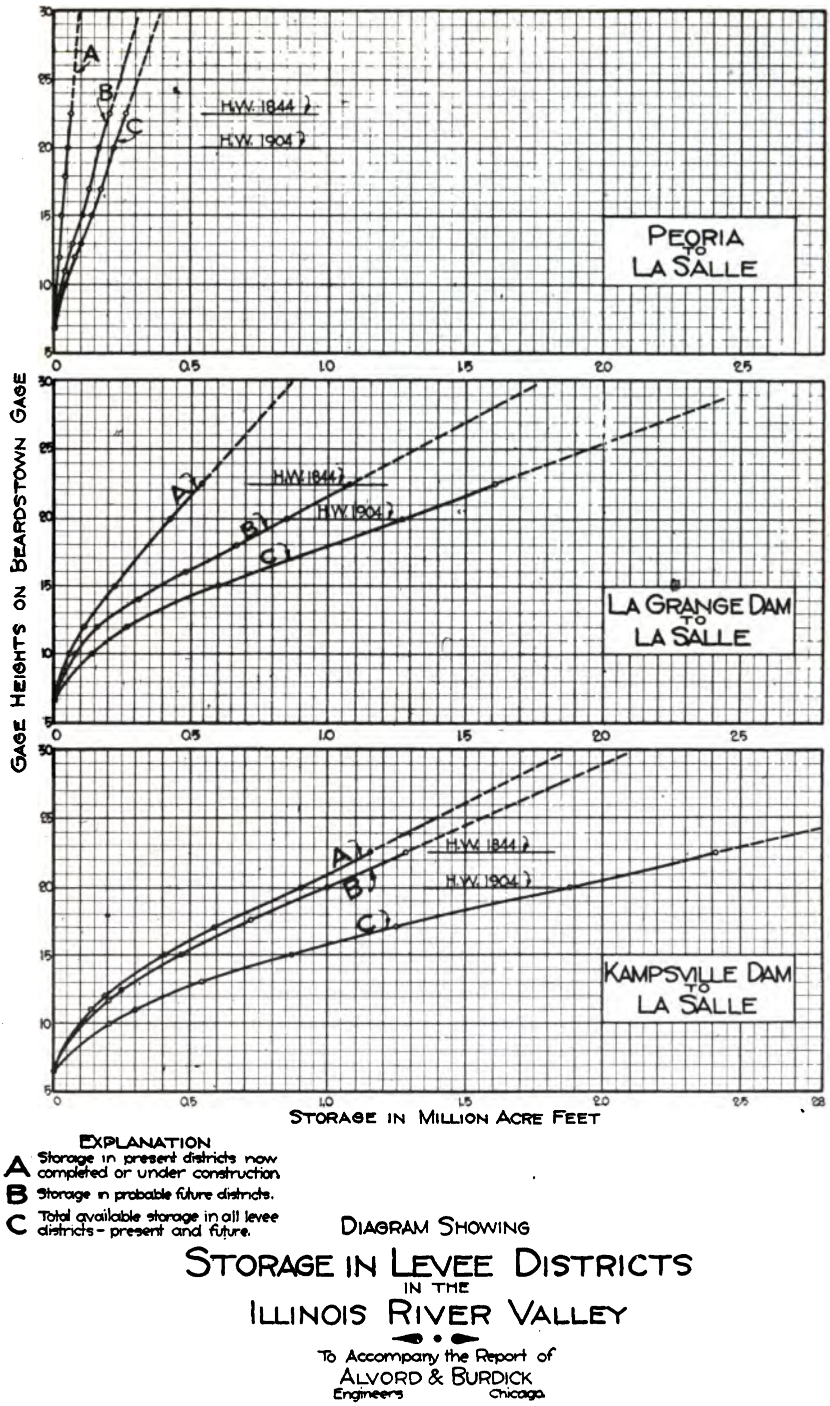

A
B
C
H.W. 1844
H.W. 1904
PEORIA TO LA SALLE
LA GRANGE DAM TO LA SALLE
KAMPSVILLE DAM TO LA SALLE
GAGE HEIGHTS ON BEARDSTOWN GAGE
STORAGE IN MILLION ACRE FEET
0
0.5
1.0
1.5
2.0
2.5
2.8
5
10
15
20
25
30
EXPLANATION
A Storage in present districts now completed or under construction.
B Storage in probable future districts.
C Total available storage in all levee districts - present and future.
DIAGRAM SHOWING
STORAGE IN LEVEE DISTRICTS
IN THE
ILLINOIS RIVER VALLEY
To Accompany the Report of
ALVORD & BURDICK
Engineers Chicago

FIGURE 37.

now prevails between Kampsville and LaGrange, is estimated at about 1,920,000 acre-feet.

It is estimated, therefore, that robbing the valley of 920,000 acre-feet would increase the flood rate of 1904 by only about 5 per cent, and that the ultimate possible levee operations would tend to increase the flood rate only slightly more than 10 per cent.

The reason for the small effect of such a large alteration in the river bottom storage doubtless lies in the fact that the storage is largely used up before the flood reaches its apex, and as the flood remains nearly stationary for several days at the apex, it is only a fraction of the upper foot of the valley storage that has an important effect on the maximum flow rates of the Illinois River. Therefore, although the construction of levee districts on the bottom lands has a restrictive effect on the passage of floods, as has been previously pointed out, the construction of these districts has a minor effect only upon the flow rates in depriving the stream of its valley storage.

As is pointed out later, this does not prevent the river storage artificially handled from producing an important effect upon the maximum flow of the stream; thus, if the levee districts may have the water excluded from them until the flood begins to approach its apex and can then be utilized to the full capacity of the districts to reduce the flood apex, large effects may be produced.

EFFECT OF APEX STORAGE.

In order that it may be determined what effects are practicable by storing a portion of the flow near the apex of great floods in certain of the levee districts built or hereafter to be built in the valley of the Illinois River, the estimates which follow have been made.

THE FUTURE RIVER VALLEY.

Out of about 398,000 acres below La Salle lying below the water surface of the great flood of 1844, it will be recalled that a total of about 171,725 acres comprise lands now leveed or around which levees are now in process of construction, and about 49,250 acres comprise lands for the protection of which levees have been proposed or are in contemplation at this time. We estimate that there is an additional area of about 75,400 acres that will ultimately be leveed probably at no distant time. This leaves about 100,000 acres which includes the river bed amounting to 28,490 acres at the low water plane of 1901, leaving slightly over 70,000 acres comprising the river banks outside of the levee systems, small areas where it is deemed probable no levees will be built on account of the narrow bottom lands, and particularly the rapidly rising bottoms where the river skirts the bluffs which bound the valley.

Fig. 36 shows levee districts now built, the districts at present proposed, and the probable future districts.

Fig. 37 shows diagrammatically the amount of acre-feet stored within the levee districts for various stages of water. Curves are shown for:

"A" Storage in present levee districts.
"B" Storage in future levee districts.
"C" Total storage in all districts present and future.

The exhibit referred to shows the above facts for the valley above Peoria; also for the valley above the La Grange dam and for the valley above the Kampsville dam. In each case La Salle is the upstream limit of the computed storage.

In all cases the storage is expressed in acre-feet, an acre-foot being equivalent to one acre flooded to a depth of one foot.

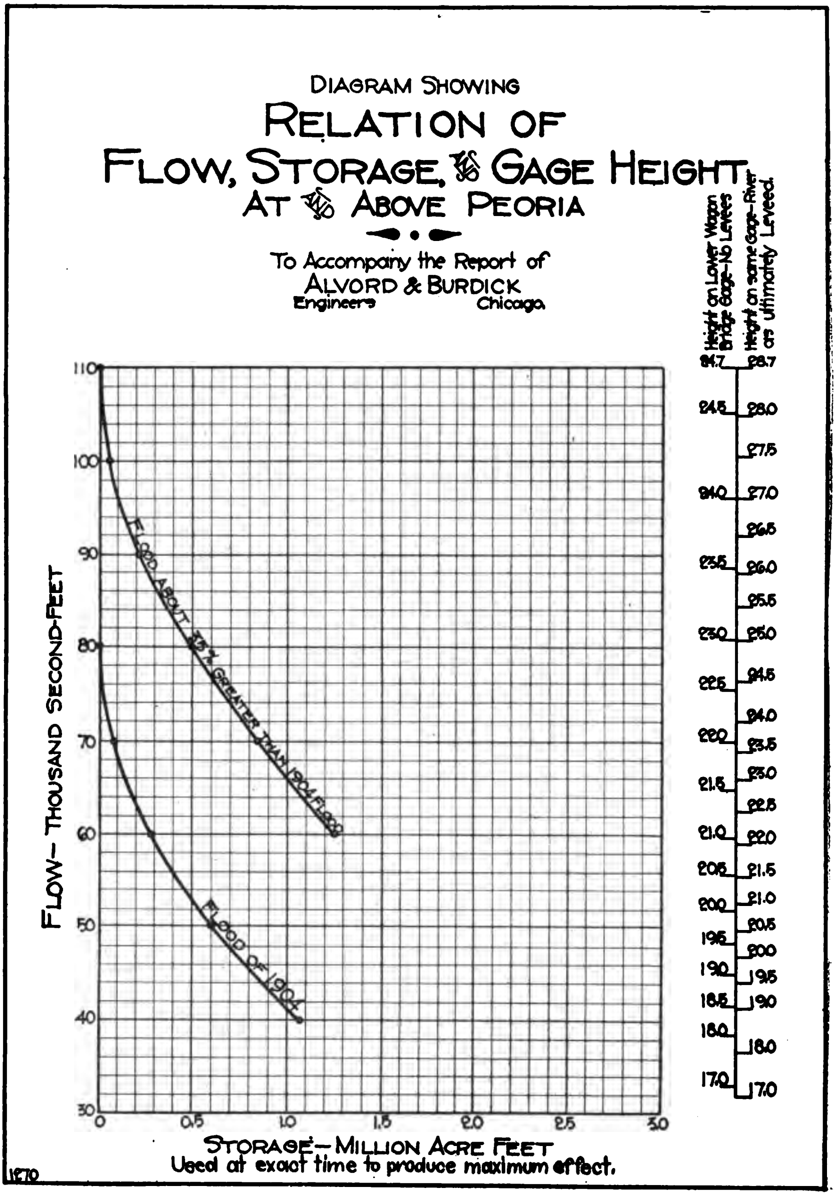


FIGURE 38.

Stage of river is expressed in gage height at Beardstown. This place is selected as being perhaps more significant over the long stretch of river than any other single gage upon the stream.

At the high water plane of 1904, the total storage inside of all levee districts present and probable future, is estimated as follows:

In districts now constructed or in process of construction...920,000 acre-feet
In districts now proposed..................................425,000 acre-feet
In future districts..575,000 acre-feet

EFFECT OF STORAGE ON FLOW.

From the rating curve at Peoria, and the daily gage heights during the flood of 1904, a hydrograph of flow during the flood was constructed, and from this hydrograph there was computed the amount of storage that would have been required to reduce the flow rates near the apex of the flood to various lesser flow rates. Table No. 39 shows this computation, and it also shows a similar computation for a flood about 35 per cent greater than the flood of 1904, assuming the greater flood to have exceeded the 1904 flood by the same percentage on every day during the flood.

TABLE NO. 39—STORAGE REQUIRED TO REDUCE FLOOD RATE ON ILLINOIS RIVER AT PEORIA.

1904 flood (80,000 second-feet.)

Average flow rate prevailing for—		Reduced flood rate for corresponding period—second-feet.	Difference or second-feet to go into storage.	Storage required—acre-feet.
Time—days.	Rate—second-feet.			
7.5	75,700	70,000	5,700	85,000
14.0	70,800	60,000	10,800	283,000
20.0	65,100	50,000	15,100	600,000
26.0	60,700	40,000	20,700	1,070,000
A greater flood (110,000 second-feet.)				
6.0	105,400	100,000	5,400	64,000
11.0	99,800	90,000	9,800	214,000
16.0	95,500	80,000	15,500	480,000
20.0	91,000	70,000	21,000	840,000
24.5	86,000	60,000	26,000	1,260,000

NOTE.—Greater flood assumed to be about 35 per cent greater than the flood of 1904, upon each day of the flood.

The effect of apex storage, as above computed, is shown diagrammatically upon Fig. 38. It is assumed that the storage would be utilized at the proper moment and in the exact proper amount to produce the maximum effect with the acre-feet in storage capacity available.

At the right of the diagram will be found the gage heights corresponding to the flows appearing on the left side of the diagram. Two scales of gage height are shown: the first corresponding to the virgin river, that is, as it existed prior to 1904; and second, our estimate of the gage heights that would usually prevail under the flows as shown at the left of the diagram in the river valley when all the bottom lands are reclaimed.

A comparison of these two gage height scales indicates that below 17 feet on the gage, the construction of levee districts has small effect upon the stage of water. It is only at the stages which produce considerable bottom land flooding and induce substantial flows on the bottom lands that the effect of the levees begins to be felt.

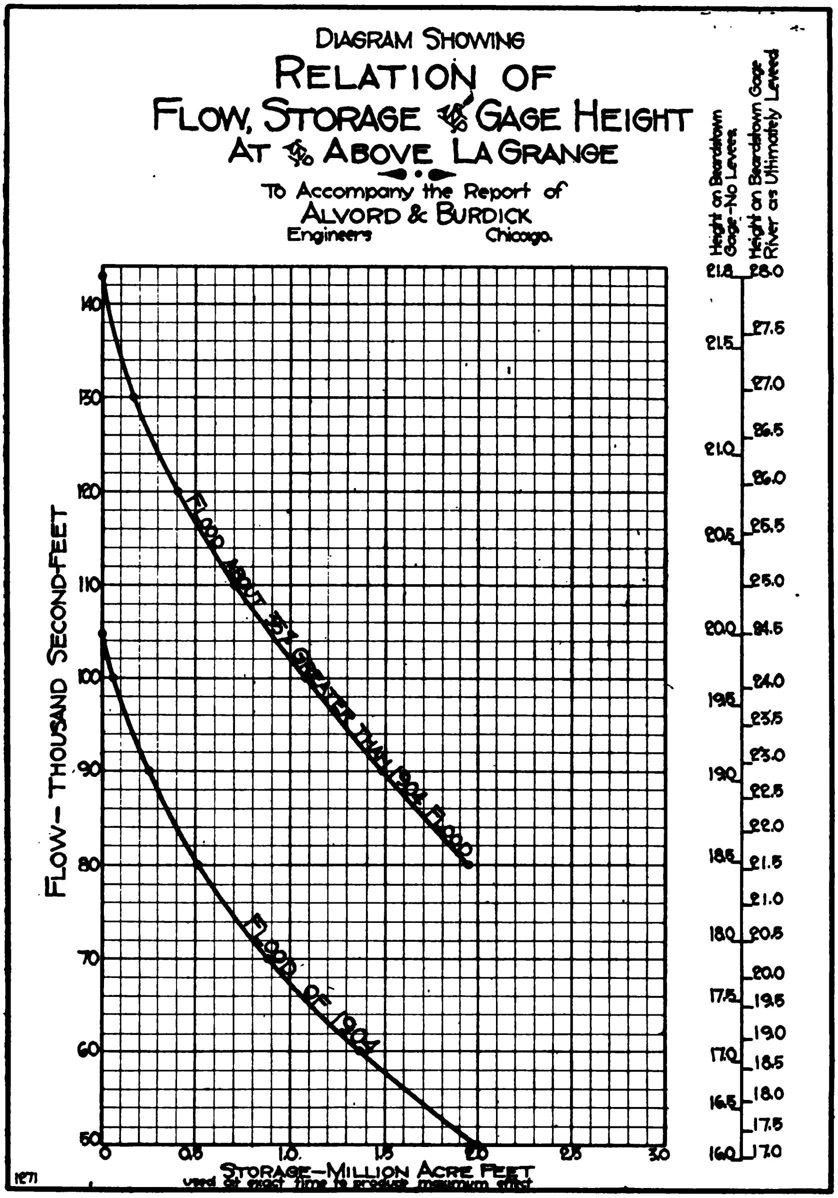


FIGURE 39.

The estimate of future gage height under a completely leveed river is based upon a computation of the gage height of a great flood (about 35 per cent greater than the flood of 1904) entering the Mississippi River at the level of the flood of 1844. It has been assumed that the new rating curve will coincide with the old rating curve at a bank-full stage, and it is further assumed that the new rating curve would vary in approximately a uniform manner for stages between these extremes. In platting the rating curves for the unleveed river, it was observed that above the bank-full stage the flow increases more rapidly than the gage height on account of the water traveling by way of the wide bottoms. With a completely leveed river it would be expected that the flows for the higher gage readings might be approximated by projecting the gage curve for stages less than bank-full. It was observed that the curve computed in the manner above explained, corresponds fairly well to the rating curve thus projected.

Fig. 39 illustrates the effect of the various amounts of storage above La Grange. This diagram has been computed in the manner previously explained for Peoria.

PROPER LEVEE HEIGHTS WITHOUT STORAGE.

Referring to Fig. 33 which is a resume of the maximum flood flow profiles computed and observed, the profile marked "H" is the estimated surface of a flood about 35 per cent greater than the flood of 1904 assumed to enter the Mississippi River at the datum elevation of the flood of 1844, and to traverse a river valley completely leveed between La Salle and Grafton. It has been previously concluded that this represents a condition which might be expected to occur about once in fifty years upon the average. It would seem reasonable to increase the height of all levees where necessary, to pass a flood of this magnitude without danger to the levee system. In our opinion it would be good policy to build all levees up to a height equivalent to 3 feet above the estimated water plane "H," corresponding to the line "L" on Fig. 34.

LEVEE HEIGHTS WITH APEX STORAGE.

The levee districts now built are not provided with facilities for using them as flood storage reservoirs in emergencies, and many of them are so improved that flooding would be disastrous. It will be less difficult to flood the districts to be constructed hereafter, for the bottom lands are less in width and it will be therefore, easier to farm them from dwellings built on ground above the high water plane.

For purposes of estimate we would assume that all districts constructed hereafter will be so built as to be usable for flood storage purposes, and will endeavor to ascertain the effect upon the maximum flood heights of the stream. Referring to Fig. 33 it will be observed that at Kampsville, very little can be accomplished in a great flood through the storage of flood waters, for the fall from Kampsville to Grafton is only about 2 feet under the conditions of 1844. If the whole flood were stored above Kampsville, the flood could therefore not be reduced more than 2 feet. It is probably impracticable to accomplish anything material by storage at this place.

At Beardstown much of the effect of the Mississippi River has disappeared. The Illinois River predominates in the relation between flow and gage-height. Referring to Fig. 39 showing the relation between flow and storage at La Grange immediately below Beardstown, and Fig. 37 showing the acre-feet in storage above the La Grange dam—it is indicated that in a great flood there would be about 850,000 acre-feet of storage above La Grange in future levee districts (Curve "B") which, if used to the best advantage, would reduce a flood of 143,000 second-feet to 108,000 second-feet. Without storage, the gage height would be about 28 feet, and with the storage stated, about 24.6 feet, a difference of about 3.4 feet at Beardstown.

A similar comparison at Peoria based on Fig. 38 and the diagram of storage above Peoria—Fig. 37 indicates that the available storage above Peoria would be instrumental in reducing the height of the great flood about 2½ feet, if used at the proper time and the water diverted to storage at proper rates to produce the maximum effect.

The line "K," Fig. 34 is drawn to roughly represent the top of the levees that would be considered reasonably safe if the storage in all future leveed districts could be utilized as apex storage for flood waters when needed. This curve coincides with curve "L" at Kampsville, departs uniformly from curve "L" to a maximum departure of 3.4 feet at Beardstown, and gradually approaches curve "L" to a departure of 2.5 feet at Peoria, retaining the same relation above Peoria. An approximate estimate, therefore, indicates that the storage stated would have the effect of reducing the practicable levee heights in amount, varying from nothing at Kampsville to 3.4 feet at Beardstown, and 2.5 feet at Peoria. With this information in hand, it would be practicable to estimate the future expenditures that will be required to build the future levee districts up to these profiles, and also to increase the height of the existing districts so as to make them safe from overflow on the two assumptions above.

BASIS OF COMPARISON.

Two procedures confront us:

"*First*—To build the levees to such height that future floods may be safely passed under the conditions when all the bottom lands are reclaimed, all districts being used for agriculture and kept dry by pumping, and

"*Second*—The construction of the levees only to such height as will be sufficient to pass the floods when using future levee districts to store flood water in a great flood."

It will be sufficient for our present purpose in making a financial comparison of these projects, to consider only the total moneys that must be hereafter expended without regard to who furnishes the money; to estimate the total revenues that may be produced by these bottoms—land and water—and to estimate comparative annual expenditures; all without regard to where the money comes from or who is benefited by the works built.

A comparison upon the above basis is enlightening for the reason that the State is interested in seeing improvements accomplished that will produce the maximum of good—in this case, the maximum of food for a given expenditure, and a comparative annual operating cost.

NEW EXPENDITURES WITH HIGH LEVEES AND NO STORAGE.

If the levees, present and future, are built up to the profile "L," (Fig. 34) we estimate that the following expenditures will be involved:

Embankments to increase existing levees at 13c per cubic yard	$2,240,000	
Stripping old levees at $1,500 per mile	292,000	
		$2,532,000
Levees immediately proposed at 12c per cubic yard	$1,750,000	
Interior improvements including pumping plants and tile drainage at $7.50 per acre	369,500	
		2,119,500
Distant future levees at 12c per cubic yard	$2,937,000	
Interior improvements, pumping plants and tile drainage at $7.50 per acre	565,800	
		3,502,800
Total		$8,154,300

If future levee districts are utilized for storage so that all levees may be constructed with tops corresponding to profile "K," Fig. 34, and assuming that future levee districts will be used for flood storage and fish culture only, pumping plants and tile drainage being omitted, but the levees being equipped with flood gates by which flood water can be discharged into each district at a rate of about 5,000 cubic feet per second, the estimated cost would be as follows:

Old levees raised at 13c per cubic yard	$1,300,000	
Stripping at $1,500 per mile	292,000	
		$1,592,000
Levees now proposed at 12c per cubic yard	$1,291,000	
Flood gates	100,000	
		1,391,000
Distant future levees at 12c per cubic yard	$2,256,000	
Flood gates	150,000	
		2,406,000
Total		$5,389,000

COMPARATIVE INCOME AND EXPENSE.

For purposes of comparison, we will assume that the operating cost of the agricultural levee districts is substantially the same as would be the cost of levee districts for the storage of flood waters and fish culture. We would further assume that 90 per cent of the land enclosed in agricultural levee districts produces $27.00 per acre per annum, which is the estimated acre yield of the past few years.

We would further assume that if the river is completely leveed, and the bottoms used for agriculture, the commercial fishery of the Illinois River will have disappeared. This assumption will be favorable to storage. We would further assume that the total yield of fish from the Illinois River will be one hundred pounds of fish per annum per acre of water surface prevailing for about half the year. This seems to have been approximately the yield prevailing in the past. (See Fig. 26.) At three cents per pound, the present American price, this would be $3.00 per acre of total water surface. At fifteen cents per pound, a price often received in Europe at the present time, this would amount to $15.00 per

acre. These yields per acre cannot be compared with the yield per acre for agricultural purposes; for the fish yield as thus computed, applies to the river surface as well as the land that may be flooded, whereas the acre yield from agriculture applies only to land.

For purposes of general comparison, we have prepared Table No. 40 which summarizes the additional investments hereinbefore estimated, and estimates the return from agriculture and fisheries. The return from fishes has been estimated upon the assumption that the flood storage districts will retain water during the major part of the spring and summer season, as may be most desirable to promote the fishery, the reservoirs being emptied in the late fall or winter in order that they may be available for flood storage in the following spring. The acreage for computing total yield is based upon the total area of the leveed district.

TABLE NO. 40—COMPARATIVE COSTS AND BENEFITS OF TWO PLANS FOR FLOOD PROTECTION.

	High levees as per profile "L".	Lower levees as per profile "K".
	No storage.	Storage.
Net investment	$8,254,300	$5,389,000
Annual Benefits, Past Prices—		
From agriculture[1]	$7,200,000	$4,150,000
From fisheries[2]	....	567,000
	$7,200,000	$4,717,000
Less interest on new investment at 6 per cent	490,000	323,000
Net comparative benefit	$6,700,000	$4,394,000
Annual Benefits at German Prices for Fish—		
From agriculture	$7,200,000	$4,150,000
From fisheries[3]	....	2,830,000
	$7,200,000	$6,657,000
Less interest on new investment at 6 per cent	490,000	323,000
Net comparative benefit	$6,710,000	$6,334,000

[1] Return from agriculture at $27 per acre on 90 per cent of land in districts.
[2] At 3 cents per pound.
[3] At 15 cents per pound.

It has been assumed that all expenses incident to the administration of agricultural levee districts and the flood storage districts will be the same, the only difference in the outgo being differences in the rental values of the moneys that would be necessarily invested. An allowance has been made for interest on the investment at 6 per cent.

Comparisons have been made upon two bases, namely, with fish at the present price of three cents per pound, and with fish at prices which may be reached in the future, it being assumed that the future may produce prices equivalent to the present German prices—about 15 cents per pound.

An examination of Table No. 40 would appear to indicate that with fish at the present price, the use of all the bottom lands for agriculture will return to the community over two million dollars more per year than could be secured by constructing lower levees and using them for

fish culture and flood storage, the existing levees being used for agriculture as at present. If, however, the comparison should be made upon the basis of German fish prices, the comparative returns would be much more nearly equal. The estimate, however, still indicates that a yearly return of nearly $400,000 more could be secured by bottom land agriculture.*

(Regardless as to whether the beds of lakes in the Illinois valley are of most value for agricultural purposes for private individuals or for flood storage and fish breeding for the public at large, the fact remains that these public waters and submerged lands cannot be seized by private parties for agricultural purposes and, consequently, the foregoing economic analyses must be modified so as to exclude such public submerged lands.

RIVERS AND LAKES COMMISSION OF ILLINOIS.)

OTHER CONSIDERATIONS.

It is true that if the flood waters are excluded from the bottom lands, the farmers must ultimately resort to fertilizers to take the place of the benefit arising from the natural flood. Experience upon the uplands of Illinois, land that was very rich when first broken, indicates that within fifty or sixty years serious deterioration will have taken place. It is estimated that an annual flood would be worth about one dollar per acre per year over a long period of years, to keep the bottom land up to standard indefinitely. It is believed that this sum is not sufficiently large to make it an object to flood the bottom lands for the purpose of enriching them, even if done only in occasional years. It is believed that the damage to structures other than land would make this practice undesirable.

It would be possible to equip all levee districts with pumping plants, agricultural drainage, as well as flood gates, using a part of the districts each year to store flood waters and promote fishing. They will be necessary for flood storage only in exceptional years, but if they are to promote the fisheries, there must be a large acreage flooded each year. No gain can come from this procedure except to benefit the land for agricultural purposes or to enrich the waters for the propagation of fish. It is believed that the gain from this procedure would not be sufficient to overcome the damages involved in flooding the farm lands, for the benefit to the farm lands would probably not exceed one dollar per acre per annum, and it is questionable how much the alternate farming and fishing would benefit the yield of fish. It seems probable that a large amount of vegetation might be grown in the flood storage reservoirs in the latter part of the summer and early fall—perhaps sufficient to answer all the purposes of enriching the fish waters.

EFFECT OF WATERWAY PROJECTS.

In order to determine approximately the effect upon flood water heights that might be occasioned by various projects heretofore proposed for improvement of navigation, we have given some consideration to three projects that have received considerable attention, namely, the Fourteen Foot Waterway, carefully investigated by the U. S. Board of

Engineers, The Deep Waterway, as proposed by the Illinois Internal Improvement Commission, and the more recent Eight Foot Waterway Link connecting the drainage canal with the Illinois River at the head of navigation.

None of these projects will so affect the flood water cross-sections as to be of material aid, or to prevent the wisdom of increasing the height of the agricultural levees.

The eight foot project requires only a small amount of dredging in the lower river, and will not affect the flood water conditions except the small effect produced by the removal of the dams which is understood to be a part of the project. This effect is very small—probably not more than two or three inches during extreme flood.

It is roughly estimated that the fourteen foot waterway project will affect extreme flood heights in amounts varying in different parts of the river, but not exceeding three inches. This does not consider the affect of the removal of the dams which would add slightly to the benefit.

The project of the Internal Improvement Commission, although in the published bulletin it is not definitely stated as regards the lower river, would appear to have the effect of reducing flood stages a little more than a foot at Peoria and Beardstown.

The data at hand will not permit of more accurate computations than these.

INCREASED WIDTH BETWEEN LEVEES.

There are certain places upon the river where the bottom lands on both sides of the river are enclosed within levees, although for the most part, the river skirts the bluff, leaving bottom lands only on one side.

The expenditures in the levees already built are too large to warrant serious consideration of moving the levees to positions further back from the river, thereby increasing the flood water cross-section. To do this would involve great expense for new levees, and would also generally require higher levees, for existing levees have generally been constructed upon the highest ground which is near the river bank, the ground sloping off inland.

In building future levees, however, careful consideration should be given to the location of the levees and the treatment of the flood plain between the levee faces with the object of maintaining a waterway adequate for the passage of great floods.

Under date of September 16, 1910, Mr. J. W. Woermann, C.E., who was assistant engineer in charge of the surveys in the report of the U. S. Engineer Board on a Fourteen Foot Waterway, reported to land-owners relative to certain levee districts on opposite sides of the river located a short distance below Pekin.

In reply to the question as to how much space it is necessary to leave between two levee districts in question, Mr. Woermann among other things stated:

"The actual discharge of the Illinois River in this reach during the flood of 1904, according to the discharge measurements taken under my direction, was about 95,000 cubic feet per second. In other words, at Sturgeon Island it appears that approximately 17,000 cubic feet per second passed through the timber or beyond the tops of the banks. For a similar flood this is the amount that should be provided for outside of the channel proper. As the average velocity outside of the channel would probably not exceed 5.0 feet

per second, this would require a supplemental cross-section of 3,400 square feet, and as the depth of the water on top of the banks was about 10 feet at this point, this would mean a supplemental width of 340 feet, provided this width was clear. This is the greatest additional width that is required in any part of this reach. At this particular point, most of this additional width can be secured by clearing Sturgeon Island. In other words, the *cleared* width at this point should be not less than 940 feet.

The next most restricted section is below the head of Scott's Lake, marked Station 756 on the government map; during the flood of 1904, the discharging capacity of the river proper was about 87,600 cubic feet per second, leaving about 8,000 cubic feet per second to be carried outside of the banks. For a velocity of 5.0 feet per second, this would require a supplemental area of 1,600 square feet. As the depth over the banks was about 8 feet at this point, the supplemental width beyond the banks should amount to not less than 200 feet. In other words, the *cleared* width at this point should be not less than 820 feet.

To allow for a factor of safety and for the uncertainty connected with the application of any formula to a large river, I would recommend that *800 feet* be taken as the minimum width to be kept clear. At Coon Hollow Island and the other islands below it, the clearing of the islands will give sufficient width. This is an important matter and must not be neglected. If the islands and banks are allowed to become thickly covered with timber and brush, their discharging capacity may be reduced to almost nothing and the flood line may be raised as much as three or four feet. The cost of the clearing should be borne equally by the two districts.

In regard to the location of levees, it is my opinion that the Spring Lake district on the whole has been quite liberal. At Coon Hollow Island the center line of their levee is only about 210 feet from the low water shore line of 1901, but in the other sections this distance is considerably larger, and in some places much greater than necessary, as shown in the accompanying table.

In locating your levee I would recommend that the center line be placed about 250 feet from the low water line of 1901, passing between the river and the several adjoining lakes, viz., Stillman Lake No. 1, Scott's Lake, Murray Lake and Kelcey Lake, making the minimum distance between center lines of levees about 1,200 feet. A fringe of timber and brush 100 feet wide is sufficient protection from wave-wash and ice.

In your supplemental letter of September 13 you state that the Spring Lake levee is 4 feet above high water mark. This is not definite as you do not state which high water. According to the information furnished me by their attorney, the top of their levee was 5 feet above the high water of 1902, or 3 feet above the high water of 1904, or 1.0 to 1.5 feet *below* the high water of 1844. I would recommend that you build your levee at least 1 foot above the high water of 1844. The combination of circumstances which produced that flood may recur at any time. Furthermore, it gives your district a valuable asset to have its levee a little higher than the one on the opposite side. If, as the result of an ice gorge or failure to keep down the timber and brush, the river should rise to an unexpected height, the overtopping of the levee on the opposite side would probably save your own."

In our opinion no levees should be permitted at a less distance apart, center to center, than the 1,200 feet recommended by Mr. Woermann. It is probable that in most places widths of 2,000 feet can reasonably be secured without sacrifice, all costs considered. This recommendation will apply as far south as the mouth of the Sangamon, with proper allowances for the increased drainage coming in below Pekin. This increased drainage is comparatively small. Below the Sangamon, the land is nearly all leveed, and there will be comparatively little occasion to pass upon this question.

It is probable that the same allowance should be made between Peoria and La Salle, for although the drainage becomes smaller at the north, the floods at La Salle are nearly as great as those at Peoria.

Where the floods must pass between two lines of levees, we would emphasize the matter spoken of by Mr. Woermann, namely, the necessity for so removing underbrush and trees that the full effect of the cross-section is secured after providing a minimum of brush for protection of the banks against wave wash. It is a question as to how such bottoms shall be kept cleared on account of the rapid growth of underbrush. No doubt much can be accomplished by clearing and pasturing. It is a problem that must be faced where the river is completely enclosed, for it will be impracticable to build the levees high enough to force the water through great lengths of bottoms covered thickly with brush.

STORAGE IN THE TRIBUTARIES.

It has been impossible to make a determinative study showing the effect of storing flood waters in the valleys of the tributaries, for the purpose of reducing the flood rates upon the Illinois River. The means at our disposal do not permit of original surveys, and there is no data available from which the practicabilities of the matter may be definitely determined.

Reservoirs upon the lower ends of the tributaries if properly distributed, will have substantially the same effect as equal volumes in the valley of the Illinois.

If reservoir sites on the tributaries could be secured of such character that the average depth of the stored water materially exceeds the average depths in the valley of the Illinois, then possibly there might be some advantage in utilizing such tributary storage. There would necessarily be sufficient advantage in reducing the area flooded to more than pay the cost of the dams necessary to create such reservoirs.

Although it is possible that investigation might show some favorable reservoir sites, it must be remembered that at equal depths equal areas will be overflowed either on Illinois bottom lands or the bottom lands of the tributaries, and unless it can be shown that a much greater average depth can be secured on the tributaries, or land flooded having much less value, and both of the propositions seem doubtful, there would seem to be no net gain to the State to protect certain bottom lands of the Illinois at the expense of flooded bottom lands elsewhere.

FLOOD PROTECTION CONCLUSION.

In the light of the figures upon the preceding pages, there would seem to us no doubt that the bottom lands will be most economically protected against flood by increasing the heights of the levees substantially to the profile marked "L" on Figure 34.

It is our conclusion, in the light of all the data which we could find, that it is impracticable to effectively use bottom land storage reservoirs for the mitigation of floods, for the reason that more effective results can be secured at less cost through increasing the heights of levees. This takes into account all possible gain that might accrue to the fisheries through handling the bottom land reservoirs in such manner that they will assist in fish propagation.

BEST USE OF REMAINING LAKES AND LANDS.

The original bottom land lakes aggregated 49,340 acres at low water. Levee operations have up to the present time reduced this lake area to about 31,600 acres. There are about 22 meandered lakes, and

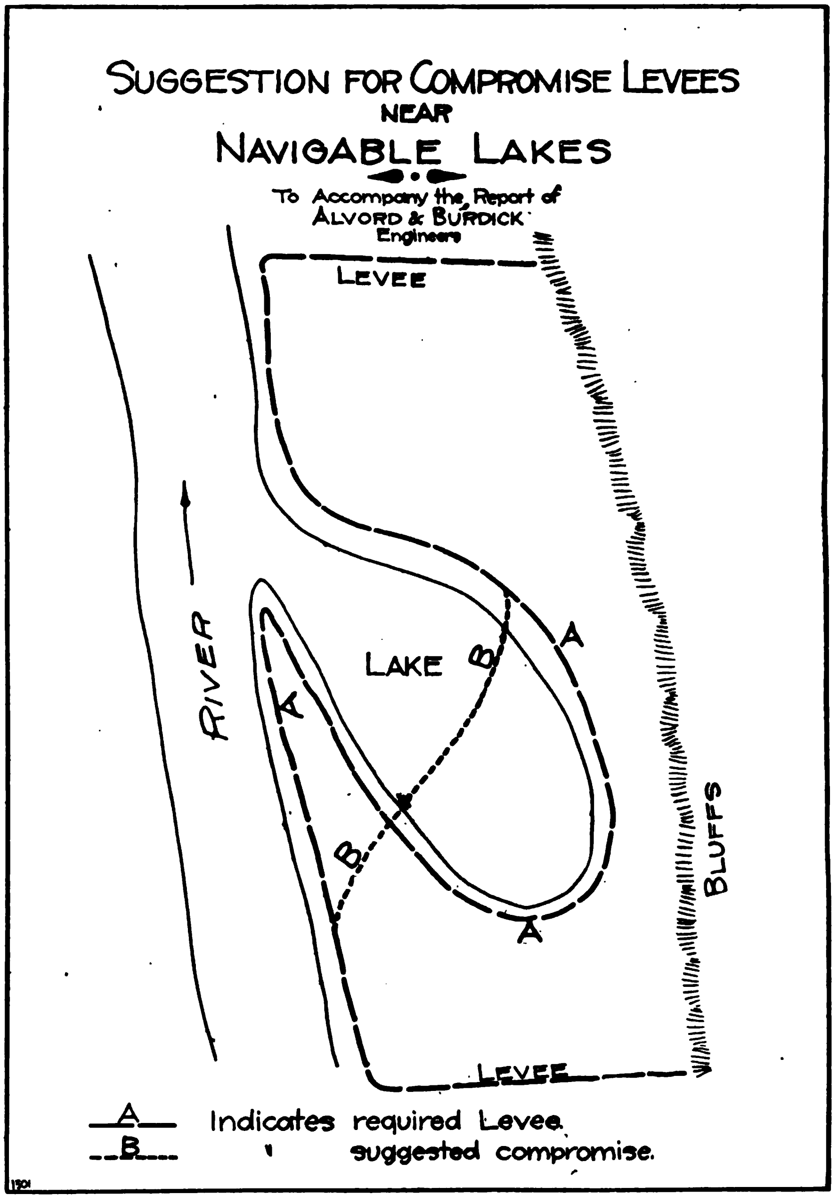


FIGURE 40.

possibly more, to which the State claims title. Table 41 is a list of the meandered lakes claimed by the Rivers and Lakes Commission to be public waters. It is stated that this list is not complete. We have added opposite the name of each lake its area by planimeter measurements from the U. S. Engineer's Survey Map.

Excluding Peoria Lake, which we have included in the area of the river as elsewhere tabulated herein, these lakes aggregate 7,002 acres, or a little less than one-quarter of the lakes remaining unleveed.

TABLE NO. 41—PARTIAL LIST OF LAKES ADJACENT TO ILLINOIS RIVER TO WHICH THE STATE CLAIMS TITLE.

	County.	Area in acres.		County.	Area in acres.
Slough near Otter Creek	Jersey	450	Slough four miles above Liverpool	Mason	......
Macoupin Slough	Greene	24	Clear Lake } Mud Lake }	Mason	810
Slough near Van Geson Island	Greene	17	Spring Lake	Tazewell	1,390
Slough near Valley City	Pike	30	Saiwell	Tazewell	42
Meredosia Lake	Scott-Cass	1,182	Pekin Lake	Tazewell	244
Hickory Slough (near mouth of Sangamon R.)	Mason	25	Gar Lake (near Sparland)	Tazewell	59
Lake Depue	Bureau	......	Huse Slough near Peru	La Salle	59
Matanzas Bay	Mason	346	Pond opposite Peru	La Salle	21
Dog Fish Lake } Quiver Lake }	Mason	290	Thompson Lake	Fulton	1,723
Liverpool Lake	Mason	290	Total		7,002

INCLOSURE OF MEANDERED LAKES.

It has been the practice, in the construction of the levee districts, to build the levees close to the river, thus cutting off the inland lakes from the stream. In certain places the title to the land surrounding the lakes may be held by private individuals who desire to dyke the same, and if the State can establish its title to the lake bed, the dyking of lands adjacent to the large lakes will be very expensive, if completely dyked, the dykes being very long, and occupying the low ground. Furthermore, the lakes thus enclosed will be of little value for the propagation of fish, if the levees are built close to the shore, for the high water levels in the spring and the higher water levels prevailing throughout the season hereafter through the increased drainage canal flows will rise upon the sides of the levees, thus destroying all the shallow water which is so advantageous to the breeding and rearing of fish.

The suggestion has been made in circumstances such as these, to compromise with the land owners by trading a portion of the lake bed for a portion of the privately held land, and to build the levees substantially as shown by line B, Figure 40; thus accomplishing for the land owner a levee of reduced cost, with reduced cost of maintenance, and accomplishing for the public a lake most practicable for the breeding and taking of fish. It would seem that this suggestion is worthy of very serious consideration in cases where applicable.

In the storage computations which we have previously made, we have assumed that ultimately practically all the bottom land will be under levee. This may require a long time for accomplishment, and it is quite possible that there are some areas lying so low, or so cut up by tributary streams, as to be uneconomical of reclamation.

It will be further noted that certain tracts are so separated by meandered lakes as to make the long line of levees required so expensive that the economy of reclamation may be doubtful. The time at our

disposal has obviously not permitted an examination of the practicability of dyking these individual tracts. It is strongly recommended that, so far as possible, these unused lands and lakes be used for the betterment of the aquatic life of the river. As to how they can best be used will probably be a subject of further study by the Department of Natural History.

CLEAN BANKS.

Competent observers state that under present conditions a great amount of the fish spawn is being destroyed through the growth of fungi, occasioned by decaying land vegetation, such as trees and brush that have been permanently inundated and killed through the increased water stages since 1910. We have heretofore pointed out the great desirability of clearing the bottoms, except for a narrow wave break in those sections of the river where both sides of the stream are leveed, in order that a clear waterway for the flood may be provided. The keeping of these lands cleared will not only serve to provide a practicable channel for flood waters but will best serve the needs of the fishes. With the levees placed well back from the river banks, as recommended in districts to be built hereafter, the grounds between the levees and the river bank, properly cleared, will be of great benefit to the aquatic life of the stream.

GAME FISHING AND HUNTING.

The waters of the Illinois River have been the rendezvous of the sportsman—both the hunter and the fisherman—for many years. It is too much to expect that the entire river bottoms will be retained in the original state of nature in order to furnish recreation grounds for those capable of benefiting by them. In general, the fate of these bottoms will doubtless be ultimately decided by financial considerations, which, as we have shown, point towards agriculture as the most profitable use of the bottoms, commercially.

It is hoped that future studies in intensive fish culture may find a way to keep the stream stocked, through a better utilization hereafter of the breeding and feeding grounds that remain.

Large expenditures are being made by cities, and the U. S. Government is not only setting aside unused lands wherever possible for playgrounds for the people, but is spending considerable sums annually for their maintenance. It is not beyond reason that the State of Illinois should obtain such bottom lands by purchase as may be necessary to augment the most favorable meandered lake holdings, for the double purpose of studying, and, if possible, increasing the aquatic life of the stream, and furnishing state parks or preserves, in which, under proper restrictions, hunting and game fishing may be pursued, and which will serve as nurseries for augmenting the commercial fishery of the stream generally.

COOPERATION WITH THE SANITARY DISTRICT.

It is generally known that damage suits, aggregating large sums, have been filed against the Sanitary District of Chicago for damage to Illinois bottom lands through the increased water delivered to the river

by the Chicago Drainage Canal. The suggestion has been made for the State and the Sanitary District to combine in the purchase of the lands damaged, or certain of them as might be most useful to the State for the purposes heretofore mentioned.

FIGURE 41.

River Banks at Recent Moderate Water Stages, Showing the Dead and Decayed Land Vegetation.

The following figures are taken from the report of Mr. Lyman E. Cooley, C. E., entitled "The Illinois River. Physical Relations and the removal of the Navigation Dams," August, 1914. Mr. Cooley places the expenditures of the Sanitary District to date on the Illinois and Des Plaines Rivers in payment of land damages, the expenditures of the Engineering Department in preparation for defense of suits, and the expenditures of the legal department, at between $500,000 and $600,000 up to December 31, 1912.

TABLE NO. 42—CLAIMS AGAINST SANITARY DISTRICT ON ACCOUNT OF DAMAGES FROM OVERFLOW ENDING DECEMBER 31, 1912.

	Permanent damage.		Temporary damage.		Total.	
	Claims.	Amount.	Claims.	Amount.	Claims.	Amount.
Utica to Havana	122	$2,474,400	46	$ 434,900	168	$2,909,300
Havana to La Grange	2	33,330	108	1,118,350	110	1,151,610
La Grange to Mouth	5	469,000	1	10,000	6	479,000
Totals	129	$2,976,730	155	$1,563,250	284	$4,539,980

The total claims pending against the district for damage on account of overflowed land up to December 31, 1912, upon the Illinois River below Utica, amount to a total of $4,539,980. The principal details of these claims are shown upon Table 42, herewith.

The total of the land and lakes in the Illinois River bottoms outside of the districts at present leveed, amounts to 219,760 acres below the flood plane of 1844, and 195,000 acres below the flood plane of 1904. The total damage claims as stated are equivalent to $20.20 per acre below the 1844 flood plane and $22.80 per acre below the flood plane of 1904.

If we exclude the lake beds outside the levee districts, amounting to 31,600 acres, the total of the damage claims per acre would be $24.00 and $27.80 per acre for the land below the flood planes of 1844 and 1904, respectively, or if we exclude from the acreage of land those acres for the protection of which levee districts are now projected, the land acreage will be reduced by an additional amount of 49,250 acres, and the total of the damage claims per acre, respectively, below the 1844 flood plane and the flood plane of 1904, would be $32.75 and $39.70 per acre of land.

The report above referred to further states:

"The additional claims preferred but not yet entered of suit will raise the total to about eight million dollars."

Eight million dollars in damages will serve to nearly double the figures above mentioned.

With regard to the value of the bottom lands, as has been previously stated in this report, those lands leveed along the Illinois River are held at from $100 to $150 per acre. The unreclaimed low bottoms are of uncertain value. It is said that much of this land is held at about $15 per acre. Within 25 years past it is probable that all the land in the bottoms could have been purchased at from $5 to $10 per acre.

In the light of all these figures, it would seem that lands of considerable value to the public might be secured by the State through cooperation with the Sanitary District, thus relieving the District from at least a part of the heavy damage claims against it, and securing to the public permanent and undisputed possession of land well adapted to assist in the maintenance of the aquatic life of the river and at the same time to form state parks or state preserves that would accrue to the benefit of the public generally.

ACKNOWLEDGMENT.

This investigation, particularly so far as it relates to natural history, would have been impossible except for the services of Prof. Stephen A. Forbes of the State Laboratory of Natural History, who from the beginning of the investigation has advised us on all matters pertaining to his department.

We are further indebted to Mr. L. K. Sherman, C. E., Engineer Member of the Rivers and Lakes Commission, for valuable criticism and data; to Mr. R. E. Richardson, in charge of the Biological station at Havana, for much valuable information regarding the fisheries; to Prof. J. G. Mosier, of the Department of Agriculture, State University, who accompanied us upon our inspection trip and from whom we learned much relating to the agriculture of the bottom lands. We are further indebted to the members of the Rivers and Lakes Commission and the Fish and Game Commission, who also accompanied us upon our first inspection trip.

The investigations relating to agriculture and the agricultural levee districts were conducted by Prof. Leslie A. Waterbury, under our general direction and we are indebted to our assistant, Mr. R. T. Reilly, for much painstaking work in the intricate hydraulic calculations relating to the flood waterways.

Respectfully submitted,

JOHN W. ALVORD.
CHAS. B. BURDICK.
Engineers.

Chicago, Illinois, July 24, 1915.

APPENDIX I.

CHICAGO, *May 5, 1915.*

Hon. Edward F. Dunne, Governor of Illinois, Springfield, Ill.

DEAR SIR: The undersigned, the Rivers and Lakes Commission of the State of Illinois, respectfully submits the following as their findings as to the public character of Thompson Lake, a public body of water located in Fulton County, Illinois, and their recommendations in relation to the same.

Section 13 of the law creating the commission and describing its powers and duties is as follows:

It shall be the duty of said commission to make a careful investigation of each and every body of water, both river and lake, in the State of Illinois, and to ascertain to what extent, if at all, the same have been encroached upon by private interests or individuals, and wherever they believe that the same have been so encroached upon, to commence appropriate action either to recover full compensation for such wrongful encroachment, or to recover the use of the same, or of any lands improperly or unlawfully made in connection with any public river or lake for the use of the people of the State of Illinois. The right and authority hereby given and created shall not be held to be exclusive or to take from the Attorney General, or any other law officer of the State of Illinois, the right to commence suit or action.

The commission adopted the following resolution:

WHEREAS, Thompson Lake, situate in the townships of Waterford and Liverpool in the county of Fulton in the State of Illinois, is a body of water about six miles in length and from three-quarters of a mile to a mile and a half in width, and one of the largest permanent bodies of water in the State of Illinois, exclusive of Lake Michigan, and connected with the Illinois River by an inlet or outlet so-called; and,

WHEREAS, Said lake is claimed to be a navigable body of water and the best fish propagating and fish producing body of water in the State, as well as a suitable, desirable and popular place of resort for navigation, fishing, hunting and the like, and for recreation for the people of the State of Illinois, by reason whereof the said lake is of great value to the people of the State and a body of water in which the people of the State claim an interest; and

WHEREAS, It is claimed by the people of the State that the title to the bed of said lake is in the State of Illinois in trust for all the people of the State; and

WHEREAS, The ownership and title to the bed of said lake is claimed by certain individuals, nearly all of whom are nonresidents of the State of Illinois, and said individuals are assuming to be entitled to the possession and enjoyment of said lake and its facilities for navigation, fishing, hunting and the like, and for recreation to the exclusion of the people and public of said State; and

WHEREAS, It is the duty of the Rivers and Lakes Commission of the State of Illinois to protect the people of the State in their use and enjoyment of all of the public waters of the State and to see to it that the same are not encroached upon nor appropriated by private interests or individuals; and

WHEREAS, Said commission is by law vested with the power and jurisdiction to investigate conflicting claims with reference to the waters of the

State and to determine, by public hearings, with reference to any of the bodies of water in the State whether, under all the facts and circumstances and the law, they are of such a character as to constitute the same public waters of the State in which all the people have an interest and to make, enter and promulgate such orders in accordance with their findings of facts as a result of such hearings; now, therefore, be it

Resolved, That the Rivers and Lakes Commission of the State of Illinois, pursuant to statute in such case made and provided, investigate the question as to the public character of said Thompson Lake, and that to that end a public hearing be held by said commission in the city hall in the city of Havana in the county of Mason in the State of Illinois, commencing on the 10th day of March, A. D. 1915, at the hour of 10 o'clock in the forenoon, and continuing from day to day or from time to time, according to the orders of this commission, as the exigencies of the case may require, and that said commission will receive and consider evidence of all facts, history, circumstances and matters bearing upon the question as to the public character of said Thompson Lake and the title of the State to the bed thereof and the interest of the people of the State of Illinois therein, and will at the close of said hearing make such findings and enter such order as the evidence submitted and received on said hearing and the matters and things within the knowledge of said commission shall require; be it further

Resolved, That a notice of the time and place of the commencement of said hearing and the nature of the same be published for three consecutive weeks in some newspaper of general circulation published in the vicinity of said Thompson Lake, and, further, that a written notice of the time and place of the commencement of said hearing be served personally upon each of the persons who claim, either by himself or together with others associated with him, to have title to and ownership in the lands underlying the waters of said Thompson Lake, or any part thereof.

Hearings were held by the commission from time to time at Chicago and Havana, Illinois, where witnesses were heard and documentary evidence considered. The commission reports and certifies the following:

Thompson Lake is the greatest, if not the most valuable, body of water within the State of Illinois. It is said to be the best spawning ground for the feeding and advancement of fish life that there is in the State. It produces millions of pounds of fish annually, and sustains a large portion of our population, especially the people residing in the cities of Pekin, Havana, and Peoria engaged in the fish business. It is steadily enhancing in value to the advantage of these people as well as to the State as the provider of a great and prosperous industry.

Thompson Lake was surveyed by the U. S. Government partially in 1817, partially in 1827, and finally in 1842. It extends in a southerly and northerly direction about six miles, being connected with the Illinois River by an inlet about two miles south of Liverpool, Illinois, known as the Thompson Lake slough, and an outlet at the south end of said lake almost opposite the city of Havana in the State of Illinois known as the "cut road." From the survey and field notes introduced in evidence, and the testimony of expert witnesses, as well as the exhibits, it appears that the lines established in these surveys constituted what is known as meander lines and positive boundary lines of Thompson Lake. It appears from the testimony that as far back as the memory of one of the oldest living men in the vicinity of Thompson Lake, or Fulton and Mason counties, that it was used for commercial navigation for many years. Products and freight, such as grain, horses, cattle, wood, coal and building material, were shipped from the west side of the lake to one of the inlets of the river and thence to Chicago, Peoria, Pekin and Havana; also to St. Louis, Missouri.

Harry S. New, Alexander C. Ayres et al., residents of the state of Indiana, claim to be owners of the bed of Thompson Lake and in order to quiet their title filed a bill in equity in the Circuit Court of Fulton County against one William Shafer and others. The complainants endeavored to make the State of Illinois a defendant in this proceeding, but the decree entered by the court in Fulton County (a copy of which is in the possession of the Attorney General) made no finding as to the rights of the people of

the State of Illinois in said lake, but did expressly exempt the State of Illinois. The court also made a finding in favor of Harry S. New and others, of Indiana, as to their rights and interests in the land over which Thompson Lake flows as against the several defendants named in the decree. These parties are the incorporators and members of what is known as the "Thompson Lake Rod and Gun Club," a corporation under the laws of the State of Illinois composed entirely of members from the state of Indiana.

The testimony introduced and copies of documents, deeds, etc., read before the commission and placed in our record, disclose that Harry S. New et al., did not hold all of the abutting lands adjoining Thompson Lake to the meander lines of said lake in fee simple (as he and his cocomplainants claim in their bill filed in Fulton County). It appears that they have no title in fee to large tracts of this land, as disclosed from the abstract prepared by us. This abstract will show that no such fee simple title, or in fact any title, could lodge in these complaints. The record will further show that in every instance the land abutting Thompson Lake was conveyed to the water's edge only and, therefore, could not affect the title of what is called the bed of Thompson Lake.

The evidence also discloses that all of the surveys which were made from 1817 down to the present date contain a sharp marked water line, declaring Thompson Lake to be a lake, although it appears from an examination of the plats of survey that direct section lines were drawn across this body of water as if it had been a survey of land. This has been explained by competent evidence that the reason for the laying of section corners in the lake was because the surveys were made during the winter when there was sufficient ice to carry the surveying crew and, therefore, it was easier to draw the straight lines of the sections across the ice than it would have been by calculations had the surveys been made in the summer. In other words, it was for the convenience of the surveyors and to their financial advantage because at the time they were paid for their work by the mile.

It appears that the inlet and outlet known as the Thompson Lake slough and the "cut road" have existed for all time as a connection between the lake and the Illinois River; that the upper inlet, or Thompson Lake slough, has always been deep enough and wide enough to permit craft of various kinds, including steamboats drawing as much as 4½ feet of water, to enter the lake from the Illinois River, or enter the Illinois River from the lake, and that during low water stages commercial craft could navigate in Thompson Lake when they could not do so in parts of the Illinois River.

We quote the following paragraph from the report of the Submerged and Shore Lands Legislative Investigating Committee, page 170, prepared under the direction of the Hon. B. M. Chiperfield, chairman:

"From an investigation it is apparent that this lake has been subject to navigation for useful commerce for many years, and if this assumption is true, it is without question the property of the State of Illinois."

We have concluded that should either the county judge or the county clerk of Fulton County attempt to convey the land lying under this lake within the lines established by United States government surveys of 1817, 1827 and 1842, that the said deeds or decree affecting this land would be void, and our investigation leads us to believe that the lake within these lines could not be a part of such lands as could be conveyed under what is known as the "Swamp Act" (which was contended in the Fulton County Court), because the ownership of the lake at the time was in the State of Illinois prior to the creation of what is known as the Swamp Act of 1850 and prior to the admission of the State of Illinois into the Union of States in 1818. It is our conclusion that it is one of the bodies of water which has been exempt from the effect of this Swamp Act although (accidentally) embraced in the description given by the then United States government officials.

Our investigation of Thompson Lake causes us to believe that the attempt of Harry S. New, Alexander C. Ayres et al., the respondents who claim title to the bed of this lake, has been from its inception an attempt on their part to take from the people of the State of Illinois a large tract of valuable public property without compensation and to destroy a great industry, namely, the propagation of fish life, for the purpose of draining

the lake and converting it to their own private ownership and use. These parties have sought to prevent the commission, on two different occasions, from investigating the public character of this lake. On one occasion, when a hearing was set by the commission, they secured an injunction against William Shafer and others from appearing before the commission after they had been subpœnaed, as provided by law. On another occasion, the day before the last hearing at Havana, Illinois, the attorneys representing the same parties appeared before his honor Judge Landis in the United States District Court and sought to have the commission enjoined from proceeding with its investigation of the public character of this lake. Their bill was dismissed by the court.

We, therefore, in consideration of all the facts and circumstances in connection with the public character of Thompson Lake, conclude that the people of the State of Illinois have great rights and interests in this lake; that its integrity as a public body of water should be preserved, and in view of the litigation between the parties and the great importance of the same, as evidenced by the decree entered, we recommend that the proper officers of the State institute promptly the necessary legal proceedings to quiet the title of the people of the State of Illinois to the land over which said lake flows, or to institute and take such other action as may be deemed to be proper to protect the rights and interests of the people of the State of Illinois in said lake.

All parties in interest, Harry S. New, Alexander C. Ayres, and others, were notified by subpœna issued by the commission to be present and take part in the hearings held at Havana and Chicago, Illinois.

Maps, plats of surveys, field notes and record of evidence are on file in the office of the commission and may be had upon request.

All of which is respectfully submitted.

ARTHUR W. CHARLES, *Chairman;*
LEROY K. SHERMAN, *Commissioner;*
THOMAS J. HEALY, *Commissioner.*

APPENDIX II.

REMOVAL OF DAMS IN THE ILLINOIS RIVER.

(From annual report of 1914.)

The Illinois Association of Drainage and Levee Districts and similar organizations have at various times passed resolutions demanding the removal of the four dams in the lower Illinois River. The Sanitary District of Chicago has at various times made attempts to have these dams removed. Considered solely from the standpoint of drainage and land overflow, these dams should be removed at once.

Section 23 of the act of 1889 to create sanitary districts and to remove obstructions in the Des Plaines and Illinois River recites as follows:

"The district * * * shall remove the dams at Henry and Copperas Creek in the Illinois River before any water shall be turned into said channel. And the canal commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers, by any drainage district or districts, to maintain a depth of not less than six feet from any dam owned by the State, to and into the first lock of the Illinois and Michigan Canal at LaSalle without the aid of any such dam, at low water, then it shall be the duty of said canal commissioners to cause such dam or dams to be removed."

After the attempt by the Sanitary District to remove these dams the Supreme Court held (Vol. 184, Ill., page 157) that the clause in section 23 of the Sanitary District Act was not mandatory but permissive, and that the dams could not be removed until an equivalent navigable depth is available without the aid of the dams. The Rivers and Lakes Commission has made computations and investigated the flow records and profile of the Illinois River, and finds that if the pending litigation of the Sanitary District in the Federal courts shall limit the flow of the Chicago Drainage Canal to 4,167 cubic feet per second, and, furthermore, if no dredging or channel improvement is undertaken, the removal of the four dams in the Illinois River will decrease the depth of water to much less than 6 feet in numerous places to the great detriment of navigation. It would be deplorable to the State of Illinois to have the flow limited to 4,167 cubic feet per second, but at the present time the fact must be met that such a condition may possibly exist. We, therefore, do not advocate the unconditional removal of these dams at the present time.

The next question is, can the dams now be removed providing compensating channel improvements be made? On page 18 of a Report by a Board of Officers of the Corps of Engineers of the U. S. Army upon a navigable waterway through the Illinois River, Document 263, 59th Congress, First Session, signed by Col. Ernst, Lieut. Col. Bixby and Major Casey, the following statement is made:

"The additional flow provided by the Chicago Drainage Canal is now 4,200 cubic feet per second. It will allow the removal of the present locks and dams, and it makes practicable the maintenance of an open channel considerably deeper than the seven feet now provided by these structures."

Our computations are in accord with this statement, but we find that considerable dredging and channel regulation work will be required to accomplish the above results. The Rivers and Lakes Commission recommends and advises as follows:

1. The four State and Federal dams in the Illinois River between Utica and the Mississippi River should be removed, subject to the provision that the dredging and channel improvement necessary to secure a minimum depth of 7 feet is insured.

2. The Sanitary District of Chicago should be permitted to remove the Henry and Copperas Creek dams, subject to specific stipulations as to dredging regulations by the State through the Rivers and Lakes Commission, or other authorized State agency.

3. The Federal appropriation of $1,000,000 for the improvement of the Illinois River (section 1 of the Rivers and Harbors Act, approved June 5, 1910, is now legally available and should be appropriated at once to dredge the lower Illinois River so that the government dams at La Grange and Kampsville may be removed and a navigable depth of 8 feet be secured without such structures.